

The Relative Age Effect in Minor Ice Hockey: Investigating the “Underdog Effect”

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Abstract

The Relative Age Effect (RAE), defined as a skewed birth date distribution, has been identified as a known phenomenon in minor ice hockey. The purpose of this study was to investigate the relationship between the RAE, physical measurements, and skating ability/in-game performance in forty-four youth male ice hockey players competing in the same age cohort. Physical anthropometrics, grip strength, in-game performance and skating abilities were measured. An RAE was found in the sample ($\chi^2(3, N = 44) = 12.18, p = 0.007$). Players born in the first half of the age cohort had longer leg length ($F(1,42) = 4.49, p = 0.04$), larger body mass ($F(1,42) = 3.90, p = 0.05$), and stronger grip strength ($F(1,42) = 7.58, p = 0.009$). Performance scores were negatively associated with grip strength ($r = -.443, p = 0.003$). Findings suggest that adequate skill development can help relatively younger players overcome physical maturity disadvantages.

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List of Abbreviations

RAE: Relative Age Effect

OIST: On-Ice Skate Test

ST: Sabre Test

TSAP: Team Sport Assessment Procedure

VP: Volume of Play

PS: Performance Score

PHV: Peak Height Velocity

LTAD: Long Term Athlete Development

Chapter 1: Introduction

Ice hockey is perhaps the most popular pastime in Canada, with over 500,000 members in various minor leagues across the nation (Hockey Canada, 2012).

Traditionally, all participants are organized by chronological age, with age cohorts spanning a maximum of 365 days. In Canada, youth and minor ice hockey leagues use January 1st as the cut-off date (Hockey Canada, 2012), thus all players in a given age cohort have birthdays in the same year, from January 1st to December 31st, inclusively.

As players mature and develop skill, selection processes are inherent for participation in more competitive cohorts. For the players, these selection processes, or ‘tryouts’, can begin as early as 7 years of age. The current minor hockey system in Canada is traditionally competition-driven rather than development-driven; thus, as is the case with other sports systems, coaches act in their best interest by selecting players whom they feel will most likely contribute to the success of their team (Helsen, Starks, & van Winckel, 1998; Mujika et al., 2009). Unfortunately, despite efforts to create a system that offers each player an equal opportunity for success, it has become evident that children born earlier in the age cohort are generally more successful in gaining a position on the teams they try out for, compared to children born later in the cohort (Barnsley & Thompson, 1988). This has resulted in a consistently skewed birth date distribution favouring the relatively older players, a phenomenon termed the Relative Age Effect (RAE; for reviews, see Cobley, Baker, Wattie, & McKenna (2009) and Musch & Grondin (2001)).

Further to this phenomenon, the smaller portion of relatively *younger* players who manage to progress to elite levels of play have been observed to excel later in their

playing careers, especially in professional ranks. Evidence shows that they have longer lasting careers (Gibbs, Jarvis, & Dufur, 2011), make more money (Ashworth & Heyndels, 2007b), and are awarded more accolades than their relatively older teammates (Ford & Williams, 2011). This RAE ‘reversal’ has been termed the *Underdog Effect* (Gibbs et al., 2011).

The explanation commonly presented to explain the RAE is that at young ages, the older players within the cohort are more likely to be superior in skill and performance, due to their higher level of physical and cognitive maturity at the time of the tryouts (Baker, Copley, Montelpare, Wattie, & Faught, 2010; Barnsley, Thompson, & Barnsley, 1985; Barnsley & Thompson, 1988; Helsen, Starkes, & van Winckel, 1998; Sherar, Baxter-Jones, Faulkner, & Russell, 2007). Alternatively, researchers have recently begun to theorize that relatively older and more physically mature players are merely perceived as being more talented, and are thus given more attention and skill development (Hancock, Adler, & Côté, 2013; Musch & Grondin, 2001; Vaeyens, Philippaerts, & Malina, 2005). Regardless of the explanation, the prevalence of the RAE suggests that organizing players based on chronological age has been insufficient in creating a fair environment for all youth ice hockey players looking to progress in the sport.

To address this, the purpose of this study was to investigate the relationship between relative age and ice hockey playing ability, measured through in-game performance analysis and on-ice skating tests. A second purpose of the study was to investigate the relationship between playing ability and physical measurements.

Indirectly, this study sought to investigate possible evidence to explain why relatively older players are given preference, and why the *Underdog Effect* occurs in later years.

Chapter 2: Review of Literature

2.1 Evidence for the Existence of the RAE

The RAE was initially investigated in the school setting, where it was observed that relatively older children (children born close to the cut-off date for beginning kindergarten) were more cognitively developed compared to their relatively younger classmates (Bisanz, Morrison, & Dunn, 1995; Diamond, 1983). This led to a higher proportion of relatively younger schoolchildren being labelled as having a learning disability (Maddux, 1980), and an overrepresentation of relatively older schoolchildren earning academic awards and attending a post-graduate institution such as a university (Russell & Startup, 1980). In the sport context, the RAE was first investigated when the birthdates of the players on several teams in the National Hockey League (NHL) and Canadian 'Major Junior' ice hockey were discovered to be skewed towards the beginning of the year (Barnsley et al., 1985). Researchers theorized that the RAE in this context was also the result of the organization of age cohorts, whereby players born from January 1st to December 31st of a given year compete against each other (Barnsley & Thompson, 1988). Since then, the RAE has received considerable attention from researchers in the competitive sporting domain, with research spanning across several sports and several different countries.

There exists an overwhelming body of scientific literature demonstrating the RAE in several youth sport contexts. For example, the RAE has been investigated in soccer in countries where the sport is popular. In one study, elite soccer teams representing their countries in the 1990 World Cup, as well as the U20 and U17 teams were investigated. The birth date distributions on all teams were shown to be skewed towards the beginning

of the age cohorts (Barnsley, Thompson, & Legault, 1992). Later research provided supporting evidence for the RAE in soccer, in age groups spanning from 7 years of age to senior leagues, and skill levels ranging from recreational to professional levels (Augste & Lames, 2011; Bliss & Brickley, 2011; Brewer, Balsom, Davis, & Ekblom, 1992; Brewer, Balsom, & Davis, 1995; Delorme, Boiche, & Raspud, 2010a; Delorme, Boiche, & Raspud, 2010b; Glamser & Vincent, 2004; Helsen, 2000; Helsen, Starkes, & van Winckel, 1998; Helsen, Hodges, van Winckel, & Starkes, 2000; Helsen, van Winckel, & Williams, 2005; Simmons & Paull, 2001; Vaeyens et al., 2005; Verhulst, 1992; Vincent & Glamser, 2006). Researchers have also found evidence of the RAE in basketball (Delorme & Raspud, 2009; Delorme, Chalabaev, & Raspud, 2011), baseball (Glamser & Marciani, 1992; Nakata & Sakamoto, 2011; Thompson, Barnsley, & Stebelsky, 1992; Thompson, Barnsley, & Stebelsky, 1991), American football (Daniel & Janssen, 1987; Glamser & Marciani, 1992), tennis (Edgar & O'Donoghue, 2005; Giacomini, 1999), rugby (Till et al., 2010), and handball (Schorer, Baker, Busch, Wilhelm, & Pabst, 2009).

Initially, it was suggested that confounding factors such as the season in which athletes were born affected their athletic development ('season of birth effect'), and not necessarily their relative age. However, the RAE has been identified even when controlling for different cut-off dates. Helsen and colleagues (2000) analyzed soccer players in four different age groups in the Belgian Soccer federation during the 1996-1997 and 1997-1998 competitive seasons. During the initial year under study, the cut-off date for the cohort was August 1st, whereas during the second year the cut-off date was January 1st. As hypothesized, the RAE shifted such that in both years, the players with births shortly after each cut-off date, who were relatively older, were overrepresented.

These results were replicated by four other studies investigating athletes in competitive European soccer leagues (Helsen et al., 2005; Musch & Hay, 1999; Simmons & Paull, 2001; Vaeyens et al., 2005).

Research suggests that it is unlikely that the season in which players are born influences athletic development. For example, all minor ice hockey players in North America and many parts of Europe play in developmental leagues that have a January 1st cut-off date, which is in the middle of the winter season (Musch & Grondin, 2001). A study of the birth distributions of elite tennis players showed that births in developmental leagues throughout 13 countries with varying climates consistently showed a bias of birth frequencies in the early parts of the selection years (Edgar & O'Donoghue, 2005). Socio-cultural influences on the birth distribution of athletes have also been investigated. In soccer leagues across Germany, Japan, Brazil and Australia significant birth date effects were observed, demonstrating that the RAE is independent of climate and socio-cultural characteristics (Musch & Hay, 1999).

The RAE has also been identified at very young ages (Cobley et al., 2009). Initially, it was hypothesized that the RAE would occur during the pubertal years (12-14 for boys, 10-12 for girls) due to the increased variance in physical size and strength within a 1 year age group during this time (Barnsley et al., 1985). Further research has revealed RAEs in children as young as 5 years of age (Barnsley & Thompson, 1988; Hancock, Ste-Marie, & Young, 2013; Helsen, Starks, & van Winckel, 1998), an age during which physical development is less variable (Malina, 1994). Other areas in which the RAE has been observed in children includes French female soccer players (Delorme, Boiche, & Raspaud, 2010a), boys' soccer age 10-12 at the representative level (Helsen,

2000), and in T-ball in males as early as ages 4-6 (Thompson et al., 1992). Interestingly, one study provided strong evidence of the RAE in hockey players as young as 5 years, playing in an introductory league where talent selection was non-existent (Hancock, Ste-Marie et al., 2013).

The RAE has been investigated in female leagues across several different sports (Baxter-Jones, 1995; Edgar & O'Donoghue, 2005; Helsen et al., 2005; O'Donoghue, Edgar, & McLaughlin, 2004; Vincent & Glamser, 2006). In a recent meta-analysis that included studies investigating the RAE in female sports, "sex made little difference to the overall odds ratios", however the magnitude was slightly smaller (Cobley et al., 2009). Moreover, one study failed to observe evidence of an RAE in basketball, soccer and handball players (Goldschmied, 2011). Unfortunately, compared to research into male athletes, the quantity of studies in female athletes is clearly lacking. A large proportion of the research has been conducted on senior level players, with no studies solely investigating a possible RAE in youth female sports. Secondly, no studies have investigated the causes of the RAE in female sports, despite their importance based on the fact that results are less consistent.

Evidence for the RAE in Canadian ice hockey is extensive, at both the minor league (Baker et al., 2010; Barnsley & Thompson, 1988; Hancock, Young, & Ste-Marie, 2011; Hancock, Ste-Marie et al., 2013; Nolan & Howell, 2010; Sherar et al., 2007; Sherar, Bruner, Munroe-Chandler, & Baxter-Jones, 2007; Wattie et al., 2007) and professional levels (Barnsley et al., 1985; Côté, Macdonald, Baker, & Abernethy, 2006; Nolan & Howell, 2010; Wattie, Baker, Cobley, & Montelpare, 2007). The phenomenon has also been observed at each age and skill level within various Canadian hockey

leagues. RAEs in the Edmonton Minor Hockey Association have been observed in ages 8 all the way through to age 20, at varying competitive levels (Barnsley & Thompson, 1988). Researchers have analyzed the birthdates of several ice hockey teams in Nova Scotia ranging from 8 to 15 years of age, finding that although the RAE varied in effect size, there was a statistically significant bias towards the beginning of the age cohort as early as Novice (8 years of age) when looking specifically at higher levels of competition (Boucher & Mutimer, 1994). More recent studies indicate that the RAE is still prevalent in Canadian minor ice hockey systems today, even at very young ages, demonstrating the persistence of the phenomenon (Baker et al., 2010; Hancock et al., 2011; Nolan & Howell, 2010).

2.2 Possible Explanations for the RAE

With consistent observations of the RAE in several sport contexts and at several age levels, researchers have turned to answering the question of why the RAE occurs. Research into the underlying causes in the contexts of physical development, cognitive development, socio cultural factors, experience, and structural characteristics of the sports systems will be reported in this section. The explanations presented in the literature to account for the RAE in any sport context can be grouped into two categories: initial overrepresentation of relatively older athletes due to selection preferences, and the ensuing enlargement of this inequality through the enhanced coaching and skill development from which these athletes benefit (deemed the *primary* and *secondary effects*, respectively; see Gibbs et al. (2011)).

2.2.1 The primary effects. A review of the literature on the RAE in sport concluded that competition was a necessary condition for the RAE to emerge, and that as

the competitive level of play increased, so did the effect size (Barnsley & Thompson, 1988; Musch & Grondin, 2001). It was argued that all the proposed contributing factors to the RAE (uneven levels of physical and cognitive maturation, psychological influences, experience) only appear to be of significance if the number of players competing for a position on a team outnumbers the amount of positions available. However, although direct evidence of a selection bias in favor of relatively older players has been demonstrated (Sherar et al., 2007), recent evidence (reported in the previous section) has shown that the RAE can occur even without these selection processes (Hancock et al., 2013). Another prerequisite is that the goal of the selectors (i.e. coaches) is to be competitive and win competitions, rather than provide a fair developmental atmosphere for all the potential athletes (Helsen, Starkes, & van Winckel, 1998; Mujika et al., 2009).

The theory that high competition for playing opportunities is one of the prerequisites for the RAE is supported by research that shows varying RAE effect sizes across varying contexts. For example, investigations across different sports have demonstrated that effect sizes are smaller if the sport is lower in popularity, such as Canadian volleyball, and larger in more popular sports such as soccer and ice hockey (Grondin, Deshaies, & Nault, 1984). Effect sizes have also been shown to vary within the same sport but across different countries where the popularity of the sport varies. European soccer leagues have displayed a larger effect size than soccer leagues in North America (Brewer et al., 1995; Glamser & Vincent, 2004; Helsen et al., 2005; Stanaway & Mines, 1995), and Canadian ice hockey has shown a larger effect size compared to US ice hockey (Côté et al., 2006). Studies have also found that within sports such as soccer,

rugby, ice hockey, and handball, the effect size of the RAE is larger in male leagues compared to female leagues (Cobley et al., 2009; Goldschmied, 2011; Schorer, Cobley, Busch, Brautigam, & Baker, 2009; Vincent & Glamser, 2006). Researchers have suggested that, due to socio-cultural factors, female sports have lower participation rates and thus competition for positions on a sports team is not as fierce (Vincent & Glamser, 2006). As a result, the developmental advantage belonging to the relatively older girls does not result in their overrepresentation.

The RAE effect size may also be affected by the relationship between the amount of hopeful athletes in a region and the amount of opportunities that a sports infrastructure has to offer; this has been explored by investigating a possible interaction between the birth date effect and the ‘birthplace effect’ (Côté 2006, Baker & Logan, 2007, Bruner, 2011). In their investigation, Bruner and colleagues (2011) suggested that the RAE did not exist to such an extent in smaller cities because “smaller cities represent ‘undermanned’ settings” meaning that the competition for spots on elite teams is lower due to a proportionally lower amount of hopeful players.

Studies of the RAE spanning many years have demonstrated that the effect sizes in several different sports have steadily increased. One study investigated the birth dates of Canadian NHL players born in 1900 and onward, and found that significant effect sizes began in the 1970s, and have steadily increased. The researchers speculated that, as with the case with soccer, the increased population and subsequent levels of participation in the sport, popularity of the sport, and increased media and television coverage were important factors in the emergence of the RAE (Wattie et al., 2007).

Lastly, research supports the notion that team competition and the short term goal of winning is a prerequisite for the RAE. A weaker RAE has also been demonstrated in sports that tend to delay organized competition and selection processes until later periods of development (commonly adolescence), such as baseball (Thompson et al., 1992), basketball, American football, and golf (Côté et al., 2006). This suggests that the RAE is minimized if all players are initially provided equal levels of skill development and practice.

In the following sections, the main factors that are proposed to influence this selection bias are outlined. Specifically, it is theorized that varying levels of physical cognitive maturity, psychological factors and varying levels of playing experience may cause relatively older players to be overrepresented.

2.2.1.1 physical maturation. Many sports require a certain degree of physical strength, size, speed, agility and coordination, especially if one wants to excel to competitive levels. If coaches are less concerned with giving equal opportunities to athletes in the long run and more concerned with having a winning team in the short term, it is reasonable to assume that coaches would select from the cohort of players available to them the most physically superior players (especially in sports involving physical contact) (Baxter-Jones, Helms, Baines-Preece, & Preece, 1994). This preference for players with superior physical abilities is suggested to create the environment necessary for a RAE (Barnsley et al., 1985; Baxter-Jones, 1995; Musch & Grondin, 2001).

Physical maturity has been theorized as a predictor of success in sports in which large mass and stature is advantageous (Malina, 1994), such as ice hockey (Burr et al., 2008; Burr et al., 2008; Sherar et al., 2007), basketball (Delorme & Raspaud, 2009),

soccer (Helsen, Starkes, & van Winckel, 1998) and rugby (Till et al., 2010). Conversely, lower RAE effect sizes have been observed in sports where physical maturity is not thought to provide a performance advantage, such as golf (Côté et al., 2006; Nakata & Sakamoto, 2011), dance (Van Rossum, 2006) and German handball (Schorer et al., 2009).

The extent to which physical maturity varies may explain the difference in effect size between the RAE found in female and male sports as well. Research suggests that females mature earlier than boys and do not vary in physical maturity to the same extent, which may explain the discrepancies in the effects sizes (Malina, 1994). For example, pre-pubertal differences in gross motor skills are minimal across genders, but during puberty the progression plateaus in female, whereas there is a sharp increase in males (Vincent & Glamser, 2006, Gabbard, 2000). In addition, maturational differences that positively correlate with athletic performance, such as neurological maturity, body size, anatomical structure and strength appear to have higher variability in young men leading up to post-adolescence compared to women (Patel, Pratt, & Greydanus, 2002; Tanner, 1989; Vincent & Glamser, 2006). One study investigated the birth date distribution of youth soccer players across Europe, and included a pool of players from the UEFA women's under-18 tournament (Helsen et al., 2005). The RAE was less pronounced in female players compared to male players. The authors suggested that the RAE may be smaller in effect size due to the fact that girls mature at an earlier age, resulting in a smaller degree of variance in physical maturity. They also argued that the technical component of the sport (in this case soccer) may be considered to be more important among females compared to males, lessening the effect of physical maturation on selection. Research conducted on elite youth male and female tennis players is consistent

with these results. In a recent study that analyzed the birth date distributions of female and male tennis players born between 1985 and 1989, the results suggested an interaction between gender and age on the strength of the RAE. It appeared that the percentage of female players born in the first half of the year increased from 55.6 in the junior game to 60.7 in the senior game, whereas in the male competitors these percentages decreased from 63.3 to 57.4. The authors provide two possible explanations for this interaction; first, that girls mature earlier than boys and are thus better prepared to enter the senior level game, and second, that the physical effects of the RAE advantage is lower in female cohorts due to lower physiological differences (Edgar & O'Donoghue, 2005).

Studies also provide evidence showing differences in the extent of the RAE within a particular sport across different positions. A study investigating the RAE in the UK rugby league evaluated the birth-date distributions of the players based on playing position. Results showed that out of the four positions, two showed uneven birth date distributions, one of which required a certain level of physical size and strength with which to excel (Till et al., 2010). In a similar study, the birthdates and heights of county cricket players in England were analyzed, revealing an RAE in the birth date distributions of the players in one of the four positions, and that a height advantage was at least one of the explanations (Edwards, 1994). A third study analyzed the birth date distributions of German handball players according to playing position, and found that the position to which height and weight offered an advantage (left backcourt) showed the largest RAE of all 7 positions (Schorer, Cogley, Busch, Brautigam & Baker, 2009).

Unfortunately, studies directly investigating the role of physical maturity and athletic success within an age cohort (*maturation-selection theory*) are few in number,

and fail to investigate causal relationships. Nevertheless, evidence does exist to indicate that physical maturity is a predictor of success during selection. One study investigating the height and mass of soccer players demonstrated that players within a given age group were more likely to be competing in the higher competitive level if they were taller and had greater bodymass (Helsen, Starkes, & van Winckel, 1998). Bell and colleagues (1997) investigated the results of the ratings of sporting achievement among 7,942 male and 3,508 female physical education students in England. In their study, sporting achievement was quantified by measuring the performance on 4 different sports specific activities, at least one of which being related to a team sport and at least one of which being related to an 'athletic' or 'gymnastic' type. In addition, a written component was also included for every participant. The analysis indicated that even though participation levels were even for all relative ages within the grade level, the scores of both the written component and the physical performance component were higher in the relatively older students across both genders (Bell, Massey, & Dexter, 1997).

In ice hockey, evidence exists to support the *maturation-selection theory*, however it is unclear if the underlying influence is due to anthropometric measures (stature, mass), or other less obvious traits, such as cognitive processes, strength and/or speed. Sherar and colleagues studied 208 Saskatchewan ice hockey players aged 14-15, all of whom were in contention for a spot on a provincial junior ice hockey team. Data collected included birthdates, anthropometric measures, and variables intended to predict biological maturity in the players. The selection camp comprised 3 tryouts, whereby all 208 began at the 1st tryout, 51 moved on to the second tryout, and the 3rd tryout was comprised of the 22 players selected for the team. Statistical analysis showed that as the

selection camp progressed, the relative age, size and biological maturity in the pool of remaining players increased. In addition to an RAE, the main finding in this study was that the players who were selected tended to be taller, heavier and more biologically mature than the players who were not selected (Sherar et al., 2007). Further statistical analysis revealed that physical maturation, not size, was the best predictor of success. The authors noted that this distinction is important when investigating the RAE, since at this stage of adolescence the players that are more physically mature also *tend* to be larger. In another study, researchers who found an RAE in competitive hockey players of 9-10 years of age found that the statures of all the players were above the 75th percentile for the male population of their age group (Baker et al., 2010). These studies provide evidence to support the *maturation-selection theory* (Musch & Grondin, 2001) that physical maturity has an influence on the RAE.

Another reason that relatively older players are overrepresented could be that they are more likely to have a greater level of cognitive development (Musch & Grondin, 2001). Because of this, variations in the level of cognitive development across athletes competing within the same selection year have also been discussed as contributing to the RAE in sports (Bruner, Macdonald, Pickett, & Côté, 2011; Côté et al., 2006; Medic et al., 2009; Musch & Grondin, 2001; Schorer et al., 2009; Simmons & Paull, 2001; Thompson et al., 1991; Wilson, 1998). Unfortunately, because of the difficulty in quantifying cognitive development as it relates to sport performance, much of the evidence for its role in the RAE is inferred indirectly.

In several sports, performance is dependent not only on physical attributes such as aerobic and anaerobic capacity, size, mass, speed and strength, but also on cognitive

abilities (Cox, Miles, Verde, & Rhodes, 1995; Fait, McFadyen, Zabjek, Reed, Taha, & Keightley, 2011; Gioux, Arne, Paty, & Bensch, 1984; Montgomery, 1988), and this is especially true for ice hockey (Gioux et al., 1984; Harriss, 2011; Komenda, 2011; Leavitt, 1979). During an ice hockey game, players are constantly required to make quick decisions with and without possession of the puck. The success or failure of these decisions is dependent on their ability to process their position relative to other players, as well as the speed at which the play around them is moving. It has been demonstrated in a controlled setting that an added cognitive task can affect the ability for a young ice hockey player's ability to perform the basic skating and stick handling skills fundamental to the game (Fait, 2011; Harriss, 2011; Leavitt, 1979).

Evidence of varying levels of cognitive development as a contributing factor to the RAE may be found in studies which demonstrate RAEs in athletes who are very young (e.g. ages 5-9), who do not vary significantly in physical maturity or level of playing experience and skill acquisition. Within these age groups, the RAE has been demonstrated in soccer (Delorme, Boiche, & Raspaud, 2010a; Helsen, Starkes, & van Winckel, 1998), basketball (Delorme & Raspaud, 2009) and T-ball (Thompson et al., 1992).

RAEs found in ice hockey are also not limited to age groups where players are experiencing the mid-pubescent growth spurt. Barnsley and Thompson (1988), in one of the earlier papers investigating the RAE in the Canadian minor hockey system, discovered an RAE in the highest level of play in the atom age group (ages 9 and 10), as well as a trend towards an overrepresentation of players born in the first 2 quartiles of the competition year in an under-8 division (Barnsley & Thompson, 1988). A similar

investigation into the birthdates of members of the Nova Scotia Minor Hockey League found an RAE in novice (8-9 years) ice hockey players (Boucher & Mutimer, 1994). More recent studies into the birth date distribution of Atom (aged 9-10) Canadian ice hockey players have also supported the notion that the selection bias towards the relatively older players occurs at pre-pubescent age cohorts (Hancock et al., 2011, Hancock et al, 2013). Hancock and colleagues looked at the possible affect that the removal of body checking might have on the RAE in atom (9 year old) hockey players. Results indicated that not only was the RAE present, but the removal of this physical element of the game did not consistently reduce the RAE (Hancock et al., 2011). This could have been due to the increased physical abilities of relatively older players, as well as their increased cognitive development.

In examining physical and cognitive maturation as an underlying factor for the RAE in sport, it is important to note that much of the research makes the assumption that physical maturity directly results in better performance. There exists a lack of evidence investigating the direct relationship between relative age, physical maturity, skill and performance in a specific age cohort of developing athletes (Musch & Grondin, 2001). Baker and colleagues' (2010) investigation included a comparison of physical size, playing time and relative age in 'Atom' (aged 9-10 years) male ice hockey players. Results indicated that while a significant RAE was found, neither in-game playing time nor anthropometric measurements were significantly different across birth quartiles. The authors suggested that physical size influenced player selection, thus the relatively younger players were able to play at that level because they were able to match the relatively older players in height and weight. This study appears to be the only

investigation of the relationship between relative age and physical size in a single age cohort in ice hockey. Thus it remains unclear as to *how* the varying levels of physical maturation influence individual performance or selection biases. Baxter and colleagues (1995) contended that because physical and cognitive maturation levels vary, it is reasonable to assume that selectors are more likely to favor relatively older athletes because they are bigger, stronger and faster; however the way in which these traits influence skill development and athletic performance is unclear. Hancock and colleagues (2013a) have suggested an alternate explanation for the overrepresentation of more physically mature players. They contended that “physical maturity should not be automatically equated with skill” (Hancock et al., 2013, pg. 631). They hypothesized that social agents (parents, coaches, etc) wrongfully interpret physical maturity as talent, and thus higher physical maturity would attract more encouragement and skill development. In a ‘trickle down’ effect, this is thought to also give relatively older players psychological advantages over relatively younger players.

2.2.1.2 psychological influences. Psychological differences across athletes within the same age cohort may also lead to differing levels of self-efficacy and perceived competence during competition (Woodman & Hardey, 2003). For this reason, many researchers have asserted that these psychological factors may be one of the causes of the RAE (Edgar & O'Donoghue, 2005; Glamser & Vincent, 2004; Helsen et al., 2005; Patel et al., 2002; Simmons & Paull, 2001; Thompson et al., 1991; Vaeyens et al., 2005). Hancock and colleagues (2013a) argued that players who are more physically mature receive more parental encouragement (*Matthew Effect*). Their hypothesis was partially supported by a follow-up study that observed an RAE in a league of 5 year olds, where

enrolment in the league was free of talent selection (Hancock, et al., 2013). This, coupled with the *Pygmalion Effect* (increased encouragement and attention from coaches), may result in feelings of confidence and self-efficacy regarding their own abilities, in turn leading to better performance, increased participation and a willingness to further develop their skill (*Galatea Effect*), whereas a lack of self-efficacy results in lower performance and a higher chance of dropping out of the sport altogether (Feltz, 2008; Woodman & Hardey, 2003). It has been suggested that ‘early selection for elite sport participation can become a self-fulfilling prophecy for athletes and coaches. Players begin to think of themselves as talented and are thus likely to invest more time and effort into their sport with predictable results (Vincent & Glamser, 2006 p. 33). Unfortunately, no studies have investigated the *Galatea Effect* in the context of RAE in sport. Empirical evidence supports the notion that by middle childhood (age 6-11) cognitive development is such that they clearly recognize how their personal athletic performance compares to the performance of their peers (Patel et al., 2002). Thus it can be argued that the early occurring RAE is then exacerbated thereafter, when the relatively younger players that are not selected for competitive play begin to compare themselves with their counterparts. The resulting lowering of confidence, self-esteem and motivation (Fenzel, 1992; Thompson, Barnsley, & Battle, 2004) could not only lead to lower performance and competitiveness, but could also partially account for the increased rate of sport dropout seen in the relatively younger athletes (Delorme, Boiche, & Raspaud, 2010a; Delorme et al., 2011; Helsen, Starkes, & Hodges, 1998; Larouche, Laurencelle, Grondin, & Trudeau, 2010), a process that has been referred to as ‘self-selection’ (Delorme, Boiche, & Raspaud et al., 2010b).

Researchers have also suggested that the lower RAE effect size found in female sports could be due to sociological and psychological factors. Due to social stigmas and the manner in which coaches select and give favour to the more physically mature athletes, males may be more susceptible to the negative effect of the RAE on self efficacy in the sporting context, compared to females (Delorme, Boiche, & Raspaud et al., 2010b; Vincent & Glamser, 2006). This would cause more relatively younger male athletes to ‘give up’ and dropout of the sport, rather than opting to play at a lower level of competition.

Although not providing direct support for the *Pygmalion Effect*, one study provides evidence that coaches sometimes favor relatively older players. Vaeyens and colleagues (2005) investigated the birth month of 2757 amateur and semi-professional soccer players in Belgium, along with the number of times each player was selected to play in a competition game (SEL), and how many minutes played in the game (MIN). Not only was an RAE found in this population, but the month of birth in relation to the cut-off dates were also correlated to SEL and MIN. Regardless of when the cut-off date for the competitive season, the players born early in the selection year were selected to play more often, and played more in-game minutes, and were more likely to be in the starting lineup than their relatively younger teammates (Vaeyens et al., 2005).

2.2.1.3 experience. The amount of time an athlete has devoted to developing their sport-specific skill by practicing their skill in a controlled, organized environment (deliberate practice) and in organized, competitive play (deliberate play) is influential in their performance level (Ericsson, Kramp & Tesch Romer, 1993). Therefore, it has been speculated that varying amounts of experience honing ones skill could be associated with

relative age (Musch & Grondin, 2001). Assuming that all players begin playing a particular sport at the same period of their life, the relatively older players may accrue more deliberate play and deliberate practice compared to their relatively younger counterparts, and would thus have a competitive advantage during later selection processes. Unfortunately, to date, there does not appear to be any research investigating the relationship between the RAE and the amount of the individual athletes' prior deliberate play and deliberate practice experience. One reason for this could be the fact that retrospective studies are notoriously unreliable, since it is difficult for athletes to accurately record their amount of practice and playing during the many years that they have been playing the sport.

2.2.2 the secondary effect. It has been theorized that an early selection bias in favour of relatively older players immediately gives them the advantage of increased skill development and coaching available exclusively at higher levels. Unfortunately, no data have been collected to investigate the varying amounts of deliberate play and deliberate practice offered to players of different competition levels within the same age-cohort. However, though it is only at the level of anecdotal evidence, it is reasonable to assume that Canadian minor ice hockey players receive higher levels of training resources and opportunities for skill development at the level of 'AAA' compared the less competitive 'AA' or 'A' levels.

Barnsley and colleagues (1992) were the first to notice that dropout rates in ice hockey were higher in relatively younger players, and proposed that the reason was because relatively older players were more likely to be found in more competitive leagues, where they received more rewards, better coaching and more practice and

playing time (Barnsley et al., 1992). Simmons and Paull (2001), in their 5-year longitudinal study on youth soccer players in the UK, observed that relatively older players enjoyed early recognition, which immediately set off what they called the ‘cascade effect’ of selecting from such pools of talent which gradually enlarged the RAE as the competition level increased and matured ((Simmons & Paull, 2001)). In sports at the minor league level, the age at which the participants enter into organized competition is also associated with lower RAE effect sizes. As mentioned in a previous section, evidence suggests that sports with competitive games and selections processes at later ages tend to have lower RAE effect sizes. Conversely, if early selection processes create skewed birthdates in the athletes at a young age, the increased developmental opportunities given to the more successful relatively older players can further widen this gap. Sports that focus on development early on, as opposed to competition and overall team success, may minimize this *secondary effect*.

The tendency for coaches to retain players from one competitive season to the next may be a barrier for a later developing athlete to advance to higher levels. A study of the UK rugby leagues found that over 50% of the players at representative levels in the under 13-15 age categories were retained from one selection year to the next (Till et al., 2010). In their study of the effect of a rule change eliminating bodychecking on the RAE in Canadian minor ice hockey, Hancock and colleagues (2011) compared the RAE in their first year, when bodychecking was allowed, to the second year, when bodychecking was eliminated. Their results indicated a lack of rebalancing of the birth month distributions from one year to the next, and pointed out that this could have been due to

the tendency for ice hockey coaches to select the same players from one year to the next, since they are already familiar with their capabilities.

2.3 The Underdog Effect

Recent research has produced evidence that suggests that although relatively younger players are disadvantaged early on in their playing career, they actually hold an advantage over their relatively older counterparts in later years. This new development in the already complex phenomenon of the RAE has been called the *Underdog Effect* (Gibbs et al., 2011). Evidence for this is seen in studies showing that RAE effect sizes are reduced during the progression from representative levels at adolescence or early adulthood, to professional levels (Cobley et al., 2009). The theory explaining this reduction in the RAE (and in some cases even reversal) is that the players who are relatively younger (and in general, slightly less physically mature) but who progress to elite levels of competition do so by compensating with exceptional levels of technical skills and cognitive/psychological abilities. It is presumed that in later years, their physical development continues and matches that of the relatively older teammates, and what results is a player with higher overall performance abilities. This theory has been further supported by evidence that during professional play, it is in fact the relatively *younger* players who have longer professional playing careers (Gibbs et al., 2011), earn larger salaries (Ashworth & Heyndels, 2007b), and are awarded more accolades in their respective sports (Ford & Williams, 2011) compared to their previously advantaged relatively older teammates. One study showed that during the NHL 'draft', when elite 'Junior' ice hockey players make the progression to the NHL, it was in fact the relatively

younger Junior players that were drafted earlier, suggesting that NHL scouts favoured relatively younger prospects (Baker & Logan, 2007; Gibbs et al., 2011).

At the present time the explanation for how relatively younger players progress to elite levels by compensating for the lower physical maturity is speculation. As stated above, it is theorized that they overcome their physical disadvantage through superior technical skills, or superior cognitive abilities that translate to ice hockey performance. This is at the level of speculation, as the relationship between relative age, physical variables, performance and skill development within players of a single cohort has yet to be investigated.

2.4 Purpose

The purpose of this study was to investigate the relationship between relative age and ice hockey playing ability, measured through in-game performance analysis and on-ice skating tests. A secondary purpose of the study was to investigate the relationship between playing ability and physical maturity measurements.

Hypothesis 1: Physical measurements will be larger in relatively older players.

Hypothesis 2: Skating ability/in-game performance measures will be higher in relatively younger players.

Hypothesis 3: There will be a negative correlation between physical measurements (height, body mass, grip strength) and skating ability/in-game performance.

2.5 Significance of Results

The results of this study add to the growing body of literature investigating the factors contributing to the RAE in the sport of ice hockey at the minor league level.

While research that explores the relationship between birth date distribution and varying

levels of physical maturity and ice hockey performance does exist (Baker et al., 2010; Sherar et al., 2007), it is limited. There has been a lack of research examining the relationship between in-game performance, skating ability, physical size/strength, and relative age in ice hockey at the minor league level in a single cohort. Thus, researchers have been left to speculate as to why more physically mature players are overrepresented. This was the first study to address this by investigating the relative age and physical maturity of players in a single age cohort, and comparing them to their skating ability and in-game performance. Indirectly, the findings of this study provide insight into why relatively older players are given preference, and why the *Underdog Effect* occurs in later years.

The Relative Age Effect could be considered a negative outcome of the age-cohort system of organizing players for competition. The results provide additional insight into what future action should be taken to address the RAE. This may ultimately enhance the fairness of the system and increase the talent in the pool of players who are considered for professional play later on (Addona & Yates, 2010; Mujika et al., 2009).

2.6 Limitations

1. The limitations to this study are both theoretical and practical in scope. The first is the assumption that the birth month distribution of the players who began playing in the league is the same as that of the general population. Results of some studies have suggested that it is possible that relatively older players are slightly more likely to begin playing in an organized league, not just excelling within it (Delorme & Raspud, 2009; Delorme, Boiche, & Raspud, 2010; Delorme et al., 2011; Hancock, Ste-Marie et al., 2013). Thus, there is the

possibility that the birthdates of players who attended tryouts are already biased towards the beginning of the cut-off date, in which case a subsequent date of birth bias in the successful players may not necessarily indicate a selection bias.

2. The characteristics of the participants in the sample used in this study may limit the external validity. The sample will consist of all male ice hockey players, limiting the application of the findings to the male population of Canadian ice hockey players.
3. Some aspects of the skating test conditions were not able to be standardized to an optimal degree across all participants. Testing was conducted at different times of the day, and at different arenas which may have had varying levels of ice quality.

2.7 Delimitations

1. One concern that sports science researchers have when collecting data on athletes is that of the ability of the data to represent the sport-specific abilities of the participants. This study included data collected on the ice as opposed to a laboratory environment, meaning that the skating test results more accurately represented their skating performance during a competitive game. The participants used their own equipment and conduct the trials with their own team.
2. The inclusion of a measurement of the players' in-game performances strengthened our ability to answer our research question. This study aimed to investigate possible attributes that relatively younger players may possess that would give them the ability to overcome their lower level of physical maturity. Although skating is indeed considered the main fundamental skill at the core of ice hockey, there are other technical skills possessed by players that are not able

to be observed or measured by skating tests alone. The inclusion of an in-game assessment provided the ability to measure these ‘hidden’ qualities.

3. The study design allowed for the testing of Minor Midget (aged 15-16) AAA hockey players. This is the dominant level at this age group, and is the ‘draft year’ for athletes who are hoping to progress to even higher levels in the sport. This means that the participants are highly representative of the league’s elite talent pool.

Chapter 3: Methods

3.1 Participants

Forty-four ($N = 44$) male AAA ice hockey players from three minor midget AAA teams currently playing in the Ontario Minor Hockey Association (OMHA) participated in this study. Coaches were contacted and invited to volunteer for their team to participate in the study as a whole, although participation for each player was voluntary. Coaches were selected based on the region in which the team was based, as well as the scheduling availability of the team. All teams were recruited from the 1998 age cohort, meaning all players were born on or between January 1st 1998 and December 31st 1998. The playing positions of the players were restricted to defense and forwards. All participants were actively competing and injury free. Formal consent from participants and parents/guardians were obtained in writing prior to the beginning of the study (Appendix A). This study received ethical approval from the Brock University Research Ethics Board (file #12-259).

3.2 Experimental Design

A pilot study was conducted during the 2012-2013 ice hockey season, using an observational cross-sectional study design. The purpose of this pilot study was to investigate if a RAE was present in a sample of minor midget AAA hockey players. The results indicated evidence of an RAE in the league, and provided evidence that physical size and strength was higher in players born earlier in the cohort (see Appendix D). This informed the present study, which also used the same study design but with two additional variables that measured playing ability. Participants were recruited from the same age division (Minor Midget) and playing level (AAA) as the pilot study. Each

participant was measured for physical size, grip strength, skating ability, in-game performance, and relative age, with all variables measured within a 3 week time period. Data for all variables were collected during the 2013-2014 ice hockey season.

3.3 Determination of Relative Age

Relative Age was defined as the age of an individual relative to the age cohort in which they were playing (Barnsley et al., 1985). To determine relative age, the participants were asked to record their birth date, including the year, birth month and day (Appendix B). Relative age was coded as the birth quartile, relative to the age cohort, in which players were born. For example, a birthdate in January, February or March was coded as quartile one (Barnsley et al., 1985).

3.4 Playing Experience

The level of playing experience, including the number of years playing ‘AAA’, ‘AA’ and/or ‘A’ ice hockey, and the total number of years playing any type of organized ice hockey was recorded in the questionnaire (Appendix B). This was measured in order to provide a history of the participants’ ice hockey-related skill development.

3.5 Anthropometric Measures

Anthropometric measurements collected included body mass (kg), standing height (cm) and sitting height (cm) of each participant. In order to determine leg length, the seated height of the participant was subtracted from their standing height (Sherar et al., 2007). Participants were asked to wear loose-fitting clothing and were barefooted.

3.6 Grip Strength

Hand grip strength measurements were determined using a digital dynamometer interfaced with an automated instructional software program. Participants were

instructed to stand during the test, with their hands at their sides, in front of a computer monitor on which instructions were provided. The dynamometer was held in one hand in a standard position with shoulders adducted, with the forearm in a neutral position and the wrist in a neutral position just necessary to hold the device (Hager-Ross & Rosblad, 2002). Towels were available if the participant needed to dry the hand, in order to ensure proper grip during the test. During each trial, the participant squeezed the dynamometer for 5 seconds, during which time peak force (lbf) was recorded. After the initial trial, the participants repeated the procedure with the other hand. This cycle was repeated, for a total of 4 trials. Hand grip strength was represented as the highest recorded peak force measured among the 4 trials (Hager-Ross & Rosblad, 2002).

3.7 On-Ice Skating Test Battery

Each participant completed a battery of eight timed on-ice skating drills designed to represent ice-hockey related skating abilities. Participants were dressed in full hockey equipment, and used their own sticks and skates, with skates sharpened to their own specifications. Prior to performing the on-ice skating drills, participants completed a standardized on-ice warm-up consisting of 10 minutes of brisk skating around the rink. All tests were conducted in the same order across all participants, ensuring that each player had an equal and adequate rest period. The time required to complete each test was measured using a photoelectric timing system, and recorded to the nearest thousandth of a second. The time to complete each test was used to represent the on-ice skating skill measures. Verbal encouragement was provided to all participants throughout the study. The total battery took approximately 1.5 hours per team.

3.8 In-game Performance Assessment

An assessment of each participants' in-game performance was conducted using the Team Sport Assessment Procedure (TSAP) (Gréhaigne, Godbout, & Bouthier, 1997), adapted to ice hockey (Nadeau, Richard et al., 2008). A regularly scheduled competitive game was videotaped, with two cameras strategically positioned on either side of the rink to capture the gameplay footage. The videotape was imported into Dartfish TeamPro performance analysis software, version 6.0 (Fribourg, Switzerland) for TSAP analysis. The TSAP included a list of performance variables that are typically performed by both the forwards and defensemen, such as successful passes, winning a battle for the puck, shots on goal, etc. For each individual player, these actions were observed and tallied, and from this the Performance Score (PS) and Volume of Play (VP) was determined for each player (Appendix C).

3.9 Statistical Analysis

Descriptive statistics on all physical measurements, skating test times and in-game performance measures were completed and presented by mean (M) and standard deviation (SD). To investigate a possible RAE in the participants, expected birth frequencies in each quartile was set to 25%. Chi squared analysis was used to measure the difference between the observed and expected frequencies. This procedure was repeated for forwards and defensemen, in order to investigate if the RAE was present regardless of playing position. To investigate the first hypothesis, an Analysis of Variance (ANOVA) was used to compare anthropometric measurements and grip strength across birth quartiles. Due to the small sample size, this procedure was repeated for measurements across the first and second half of the cohort.

To investigate the second hypothesis, the sum total of each individual skating drill, with the exception of the final drill, was calculated as the On-Ice Skate Time (OIST). The final skating drill was the Sabre Test (ST), a test that combined all aspects of skating ability, and was thus analyzed separately. An ANOVA was performed to investigate differences in mean ranks of OIST, ST, PS and VP across quartiles, and across the first and second half of the cohort.

To investigate the third hypothesis, Pearson Correlation Coefficients were used to measure the association between physical measurements and the OIST, ST, VP and PS. All analyses were conducted using Statistical Package for the Social Sciences (SPSS) Inc. Software, version 20 (IBM, Chicago, IL). An alpha level was set at $p \leq 0.05$.

Chapter 4: Results

Analysis of birth date distribution by birth quartiles are presented in Figure 2. A chi-squared analysis of the overall sample revealed a significant RAE within the sample of players tested, $\chi^2(3, N = 44) = 12.18, p = 0.007$. When differentiating between forwards and defensemen, a significant RAE was found in the forwards, $\chi^2(3, n = 26) = 9.077, p = 0.028$. However, an RAE was not significant among defensemen, $\chi^2(3, n = 18) = 7.33, p = 0.062$ (Figure 2).

Overall and position-specific descriptive statistics are presented in Table 1. There were more forwards compared to defensemen in the sample ($n = 26$ forwards, $n = 18$ defensemen), an expected outcome given that ice hockey teams have more forwards compared to defensemen. There were no significant differences in any of the physical measurement variables across positions in the sample, indicating that physical variables were not significantly different across forwards and defense. Overall and position-specific skate test times and performance score times are presented in Table 2. There were no significant differences across positions in the skating test times or the in-game performance measures, indicating that skating ability and performance scores were not biased towards a playing position.

When an ANOVA was used to compare physical measurements across quartiles (Table 3), significant differences were revealed in grip strength only. When mean values were compared between the first and second half of the cohort, players born in the first half of the year were shown to have significantly larger measures in leg length, bodymass and grip strength (Table 5).

Descriptive statistics and ANOVA results for the on-ice skating tests and in-game performance measures across birth quartiles are presented in Table 4. No significant differences were observed across quartiles for mean values in the OIST, ST, or VP. A significant difference in PS across quartiles was observed, however no association between quartile and mean rank was seen, suggesting that PS did not vary according to relative age. A subsequent ANOVA for these variables across the first and second half of the cohort found no significant differences in OIST, ST, VP or PS (Table 6).

Pearson correlations among physical measurements and performance variables are presented in Table 7. Statistically significant correlations were found between grip strength and performance score, $r = -.443$, $p = 0.003$ (Figure 9), and between grip strength and VP, $r = -.330$, $p = .033$ (Figure 10). No significant correlations between any of the other physical measurements and performance variables were found.

Chapter 5: Discussion

This study observed an RAE in a sample of Canadian minor hockey players, a finding consistent with previous research (Barnsley et al., 1985; Barnsley & Thompson, 1988; Boucher & Mutimer, 1994; Cogley et al., 2009; Nolan & Howell, 2010). In explaining why this phenomenon occurs, the *maturation-selection theory* assumes that relatively older players possess an advantage due to their higher level of physical and cognitive maturity (Cogley et al., 2009; Musch & Grondin, 2001). From this, it is presumed that physical measurements among competitive hockey players within a cohort would be uniform, suggesting that relatively younger players ‘make the team’ because they are simply the ‘early maturers’ (Figure 1). In contrast, results of the present study indicated that leg length, bodymass and grip strength were not uniform across players within the cohort, as these measurements were higher in relatively older players. These results are in contrast to previous research that failed to find significant differences in physical size across quartiles in hockey players (Baker et al., 2010) or handball players (Schorer et al., 2009). This could be due to the differing age groups of the participants in these studies. For example, Baker and colleagues (2010) investigated hockey players who were pre-pubertal (aged 9-10), which may explain the lack of variation in size. The present study investigated adolescent players who were at an age characterized by high physical maturity variability (Malina, 1994). It has been established that youth males in the adolescent stage undergo Peak Height Velocity (PHV) at approximately 14 years of age, but experience significant increases in strength at a later date (Tanner & Whitehouse, 1978). In the context of the present study, the Minor Midget players (aged 15-16) were at a stage such that many had reached PHV, but physical strength was still highly variable.

Consistent with this, results showed that the participants varied in physical strength (grip strength) to a greater extent compared to height and bodymass (see Tables 3 and 4), and this was also consistent with preliminary results (Appendix D). Varying selection preferences unique to each coach could be another explanation. As mentioned above, all participants were playing on a total of 3 different teams, with three coaches. If coaches prefer larger players, it would be reasonable to predict that the physical size would not differ according to relative age. Important to note is the low sample size, a limitation to the present study that warrants caution when discussing results. Within the context of physical measurements, a low sample size can be particularly problematic due to the skewed birth date distribution being fundamental to the RAE. For example, only 3 births were observed in the final quartile of the cohort the participants were playing in, requiring the comparison of the measurements across the first and second halves of the cohort, in addition to quartiles.

Without any investigations into the relationship between ice hockey skill, performance and physical size/strength, researchers have been left to speculate as to why physical maturity influences the overrepresentation of relatively older athletes. Initially, it was assumed that the higher physical maturity of the relatively older players endowed them with a higher level of skill and performance (Barnsley et al., 1985; Brewer et al, 1992; Verhulst et al, 1992). In contrast to this, Hancock and colleagues (2013a) theorized that physical maturity had little to do with variation in athletic performance and skill in players within the age cohort. Instead, social agents (i.e. coaches, parents) mistakenly regard more physically mature players as being more talented, and thus the relatively older players were more likely to receive more skill development and coaching. To

address this controversy, the present study was the first to measure the skating ability and in-game performance of each player, and compare them to physical measurements and relative age.

Results indicated that although physical measurements varied with respect to relative age, skating test times and performance scores were uniform. This suggests that within an age cohort, playing ability may not be entirely dependent on relative age or physical size and strength. Although physical attributes associated with maturity (e.g. strength and speed) may increase skating ability and performance, relatively younger, smaller and weaker players had acquired the same skating abilities or techniques as their relatively older counterparts. This is consistent with a previous study that found that in soccer players aged 13-15, physical maturity and chronological age had little influence on the variation of performance in soccer-specific skill tests (Malina et al., 2005). It is important to note that this study only investigated the higher level of play (AAA), and did not compare physical attributes of these players to that of the lower levels (A and AA). However, previous research indicates that average relative age increases with playing level (Barnsley & Thompson, 1988; Boucher & Mutimer, 1992), as do physical measurements (Helsen et al, 1998; Sherar et al, 2007). This may indicate that within a league, players may 'label' themselves as A, AA or AAA early on in their careers, lowering their ability to progress to the next level, explaining the increased dropout rates of relatively younger athletes (Delorme et al, 2011; Helsen et al, 1998; Larouche et al, 2010). If, for example, a relatively younger player in AA regards AAA players as bigger and stronger, in addition to faster and more skilled, this may provide an additional

psychological barrier to advancing to the next level, consistent with the theory of ‘self selection’ observed in male youth soccer players (Delorme et al, 2010b).

Based on the *Underdog Effect*, it was predicted that the relatively younger participants would have better skating abilities and performance scores, effectively compensating for their physical disadvantage with exceptional talent. The present study failed to support this, possibly due to the age of the participants. Studies providing evidence for the *Underdog Effect* have been conducted solely in elite sports, at later age levels where physical size and strength varies little within one year (Ashworth & Heyndels, 2007a; Baker & Logan, 2007; Gibbs et al., 2011; Schorer, Cobley et al., 2009). Thus it is presumed that relatively younger players physically ‘catch up’ to the relatively older players and exceed their performance. Because the participants in the present study were still at an age when physical size and strength significantly varied, it may be that the *Underdog Effect* was yet to take effect.

Interestingly, this study did observe a negative relationship between grip strength and PS, suggesting that players with weaker grip strengths performed better. An important limitation to note is that logistical constraints restricted the strength measure to grip strength, rather than a more hockey-specific measure such as leg strength. Although grip strength cannot reliably be related to full body strength, it is reasonable to presume that stronger players would perform better in a game, due to the large physical demands of the sport. The contrary observation may be explained by the possibility that weaker players are required to compensate by developing a higher level of technique, ‘hockey IQ’ or other intangible skills that are difficult to quantify. If this occurs, it may be that when they progress in physical maturity, these abilities they were forced to develop

would provide them with an overall performance advantage. Future studies should investigate the relationship between relative age and physical maturity, skill and performance in ‘major junior’ hockey, the elite division where players (such as the participants in the present study) typically make the transition to professional hockey. Based on evidence for the *Underdog Effect* observed in professional sports, it may be reasonable to hypothesize that it is during this stage that relatively younger players physically ‘catch up’ to their relatively older counterparts and surpass them in skill and performance.

The results and analysis of the playing ability measurements in this study (on-ice skating tests, TSAP measurements) should be interpreted with caution. A limitation in this study is the limited application of the TSAP in evaluating athlete performance in real-game conditions (Molik et al., 2012; Nadeau, Godbout, & Richard, 2008; Nadeau, Richard, & Godbout, 2008). The present study was the first to apply the Team Sport Assessment Procedure (TSAP) to measure the in-game performance of participants and compare them to physical attributes and relative age. Furthermore, to determine in-game performance scores, each participant was only observed during one of their games. Nadeau and colleagues (2008) address the issue of ‘performance stability,’ defined by the fluctuation of a player’s performance from one game to the next. They cited a previous study that found that although performance does fluctuate, analysis showed that, on average, dominant players obtained higher TSAP scores than less dominant players (Nadeau et al, 2006). An assessment of ice hockey literature shows that ice hockey researchers have represented in-game performance in various ways, such as the amount of times the player’s team registered a goal for or against while the players was on the ice

(‘plus/minus’) (Peyer, Pivarnik, Eisenmann, & Vorkapich, 2011), number of total scoring chances (Green, 2006), and the draft order in which the player was selected for higher levels of play (Burr et al., 2008). Unfortunately, many of these measures are biased towards one particular skill level, playing position or team ranking. To our knowledge, no procedure other than the TSAP exists in the literature that attempts to objectively evaluate the performance of ice hockey players while controlling for position of play. Because our sample contained both forwards and defensemen, the TSAP was selected as the optimal method of quantifying in-game performance.

Collectively, the results of this study indicate that at the Minor Midget AAA level, physical size and strength are not limiting factors for a player’s ability to skate or compete successfully. If physical size and strength does have a direct influence on an athlete’s ability to obtain a skill or performance level, it was not enough to cause a significant difference in ability between participants born in the first and second half of the cohort in the present study. These findings demonstrate the need for caution when reviewing the previous literature investigating the *maturation selection theory*. For example, Sherar and colleagues (2010) investigation found that the physical maturation of the hockey players was the best predictor for success at the team tryout, and thus the authors suggested that the coaches were selecting based on physical maturation. However, no comparison between physical maturation and relative age was made within the group of successful players, and no component of individual performance was measured, thus the effect of physical maturity on skill development was not directly studied and may have been overlooked. Based on the findings of the present study, it

may be that the successful players still varied in physical maturation despite their overall physical superiority, but were all evenly matched in their ability to perform on the ice.

One previous study did find evidence of a relationship between relative age and sport performance in 16 year old males and females physical education students (Bell et al, 1997). Unfortunately, this study did not include a skill development background component for each participant. If sport-specific training, instruction and development are the most influential factors in skating ability and performance, it may be that, in the present study, the fewer number of relatively younger players still received an equal level of encouragement and skill development from their social agents from a young age, despite being smaller. This could potentially explain the uniform playing ability measurements, regardless of their relative age or physical attributes, and the relationship between relative age and physical attributes that was inconsistent with previous studies. It is likely that the coaches of the participants in this study formed their teams on the basis of on-ice performance, and may not have been selecting based on physical size and strength. The coaches were willing to overlook the smaller size or strength of a player, as long as that player could effectively contribute to the success of the team in other ways. In contrast, it may be that the players in the previous studies were selected based on their physical attributes instead of their abilities, as proposed by the authors (Baker et al, 2010; Schorer et al, 2011). It follows that the athlete's training and history of skill development may be the major determinant in their ability to perform at this level. This supports the theory outlined above by Hancock and colleagues (2013a), wherein they argue that relatively older players are, at an early age, merely *perceived* as more talented and thus more likely to be put on the path to receive the encouragement and opportunities

necessary to develop their skill. Simultaneously, fewer relatively younger players would receive the necessary opportunities, leading to higher dropout rates.

Implications for Minor Ice Hockey

The results of the present study stress the importance of skill development, regardless of physical size or strength. It could be that selectors are wrongfully choosing players to develop based partly on physical attributes, instead of technical skills and in-game performance. Several researchers have put forward possible ‘remedies’ to the RAE, such as rotating cut off dates (Boucher & Mutimer, 1994; Grondin et al., 1984), organizing players by biological as opposed to chronological age (Baxter-Jones, 1995), or restricting the amount of players born in each period throughout the selection year (Barnsley & Thompson, 1988). Unfortunately, chronological age and physical maturity cannot be controlled by hockey administration, but what can be controlled for is the skill development that each player receives. Assuming that training and deliberate practice is more influential than physical maturity with regard to developing skill, the optimal approach to this problem may be to ensure that skill development opportunities are equally provided to all players, regardless of their relative age. Consistent with this approach, previous researchers have suggested structural changes that delay selection and competitive play until the athletes reach adolescence, so that all players receive equal developmental opportunities (Cobley et al., 2009; Musch & Grondin, 2001). Regardless of what future changes are made to the structure of minor ice hockey, social agents should be mindful to provide equal skill development opportunities for all athletes within a given cohort.

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Table 1

Descriptive statistics for physical measurements and hockey-related traits

	Forwards (<i>n</i> = 26)	Defensemen (<i>n</i> = 18)	Total (<i>N</i> =44)
Relative Age (days)^a	249.12 (85.5)	219.39 (87.44)	236.95 (86.56)
Standing Height (cm)	178.13 (6.3)	178.08 (7.07)	178.11 (6.5)
Leg Length (cm)	87.52 (4.8)	86.67 (4.47)	87.17 (4.6)
Mass (kg)	74.25 (7.83)	78.19 (13.05)	75.86 (10.34)
Grip Strength (lbf)	110.66 (19.95)	108.81 (19.92)	109.9 (19.72)
Years playing AAA	4.6 (2.42)	4.61 (2.15)	4.6 (2.28)
Shoots – Left	14	10	24
Shoots – Right	12	8	20

Data are Mean (SD)

^a Relative Age was determined by calculating the amount of days between the player's birth and December 31st of that year.

Table 2

Descriptive statistics for on-ice skate tests and performance scores

	Forwards		Defense		Total	
	<i>n</i>	Mean (SD)	<i>n</i>	Mean (SD)	<i>n</i>	Mean (SD)
OIST (sec)	26	47.07 (1.54)	18	46.38 (1.56)	44	46.79 (1.57)
Sabre Test(sec)	26	19.83 (0.73)	18	19.76 (0.84)	44	19.81 (0.77)
VP	24	13.42 (7.95)	18	18.7 (9.22)	42	15.59 (8.79)
PS	24	19.11 (11.26)	18	23.25 (9.61)	42	20.80 (10.7)

N.B. Two forwards were not present for their regularly scheduled game, thus their performance scores were omitted from analysis.

Table 3

Mean values and Analysis of Variance (ANOVA) for physical measurements across quartiles

	Quartile 1 (<i>n</i> = 16)	Quartile 2 (<i>n</i> = 17)	Quartile 3 (<i>n</i> = 8)	Quartile 4 (<i>n</i> = 3)	<i>F</i>	<i>P</i>	η^2
Height (cm)	180 (6.00)	178.12 (6.48)	174.5 (7.13)	177.67 (7.51)	1.29	.29	.09
Leg Length (cm)	88.28 (4.55)	87.71 (3.99)	84.5 (5.06)	85.33 (5.86)	1.50	.23	.10
Body Mass (kg)	76.36 (7.04)	78.73 (12.87)	71.73 (9.12)	67.97 (8.71)	1.51	.23	.10
Grip Strength (lbf)*	122.38 (21.42)	106.71 (14.92)	95.39 (14.36)	100.2 (10.19)	5.10	.00	.28

Data are Mean (SD)

* Significant variation in means ($p < .05$)

Table 4

Skating and performance ANOVA results across quartiles

	Quartile 1		Quartile 2		Quartile 3		Quartile 4		<i>F</i>	<i>p</i>	η^2
	<i>n</i>	Mean (SD)	<i>n</i>	Mean (SD)	<i>n</i>	Mean (SD)	<i>n</i>	Mean (SD)			
OIST (sec)	16	46.7 (1.67)	17	46.81 (1.55)	8	46.95 (1.81)	3	46.65 (0.79)	0.05	.98	.00
Sabre (sec)	16	19.65 (0.78)	17	20.08 (0.79)	8	19.71 (0.71)	3	19.35 (0.44)	1.36	.27	.09
VP	14	15.21 (7.40)	17	17.12 (6.84)	8	20 (11.66)	3	7.33 (3.06)	1.97	.14	.13
PS	14	19.92 (9.03)	17	23.74 (8.48)	8	24.93 (13.43)	3	11.22 (2.8)	1.91	.14	.13

*Significant differences in means ($p < 0.05$)

Table 5

Physical descriptives across the first and second half of the cohort year

	1st Half (<i>n</i> = 33)	2nd Half (<i>n</i> = 11)	<i>F</i>	<i>p</i>	η^2
Height (cm)	179.03 (6.23)	175.36 (7.00)	2.69	.11	.06
Leg Length (cm)*	87.98 (4.22)	84.73 (5.00)	4.49	.04	.01
Mass (kg)*	77.58 (10.37)	70.70 (8.75)	3.90	.05	.09
Grip Strength (lbf)*	114.31 (19.74)	96.70 (13.04)	7.58	.00	.15

Data are Mean (SD)

*Significant difference in means ($p < 0.05$)

Table 6

Skating and performance measures across the first and second cohort halves

	1st Half		2nd Half		<i>F</i>	<i>p</i>	η^2
	<i>n</i>	Mean (SD)	<i>n</i>	Mean (SD)			
Total (sec)	33	46.76 (1.59)	11	46.87 (1.57)	0.04	.84	.00
Sabre (sec)	33	19.87 (.80)	11	19.62 (.65)	0.89	.35	.02
VP	31	16.26 (7.05)	11	16.55 (11.49)	0.02	.68	.00
PS	31	22.01 (8.79)	11	21.19 (12.99)	0.02	.89	.00

*Significant differences in means ($p < 0.05$)

Table 7

Pearson correlations among physical and performance variables

	Skate Test (sec) (<i>n</i> = 42)	Sabre Test (sec) (<i>n</i> = 42)	Volume of Play (<i>N</i> = 44)	Performance Score (<i>N</i> = 44)
Height (cm)	.215	.055	.012	-.123
Leg Length (cm)	.166	.091	-.038	-.116
Mass (kg)	.272	.098	-.101	-.170
Grip Strength (lbf)	-.212	-.235	-.330*	-.443*

* $p \leq 0.05$

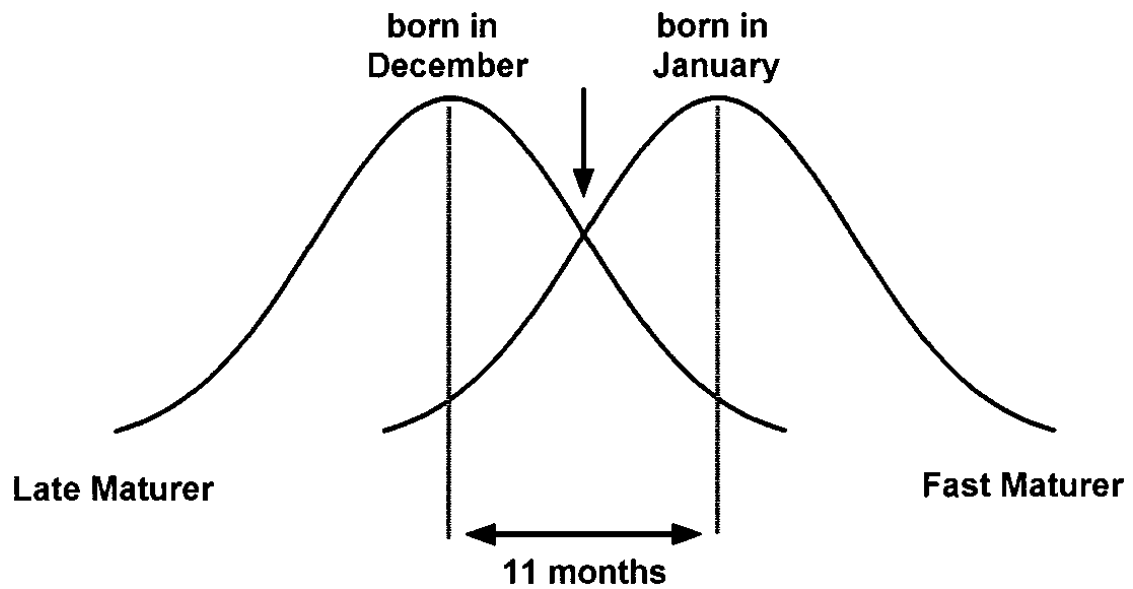


Figure 1. Maturation of two hypothetical athletes during adolescence, born 11 months apart. Adapted from 'Unequal Competition as an impediment to personal development: the Relative Age Effect in Sport.' (Musch & Grondin, 2003.)

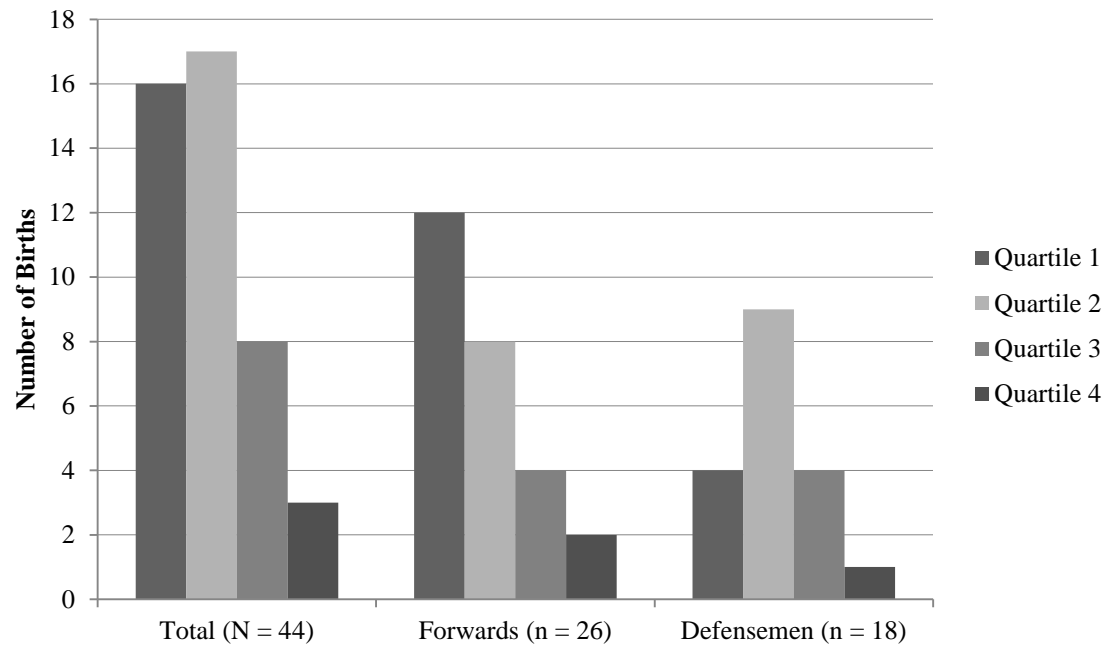


Figure 2. Distribution of births by quartile overall and by position

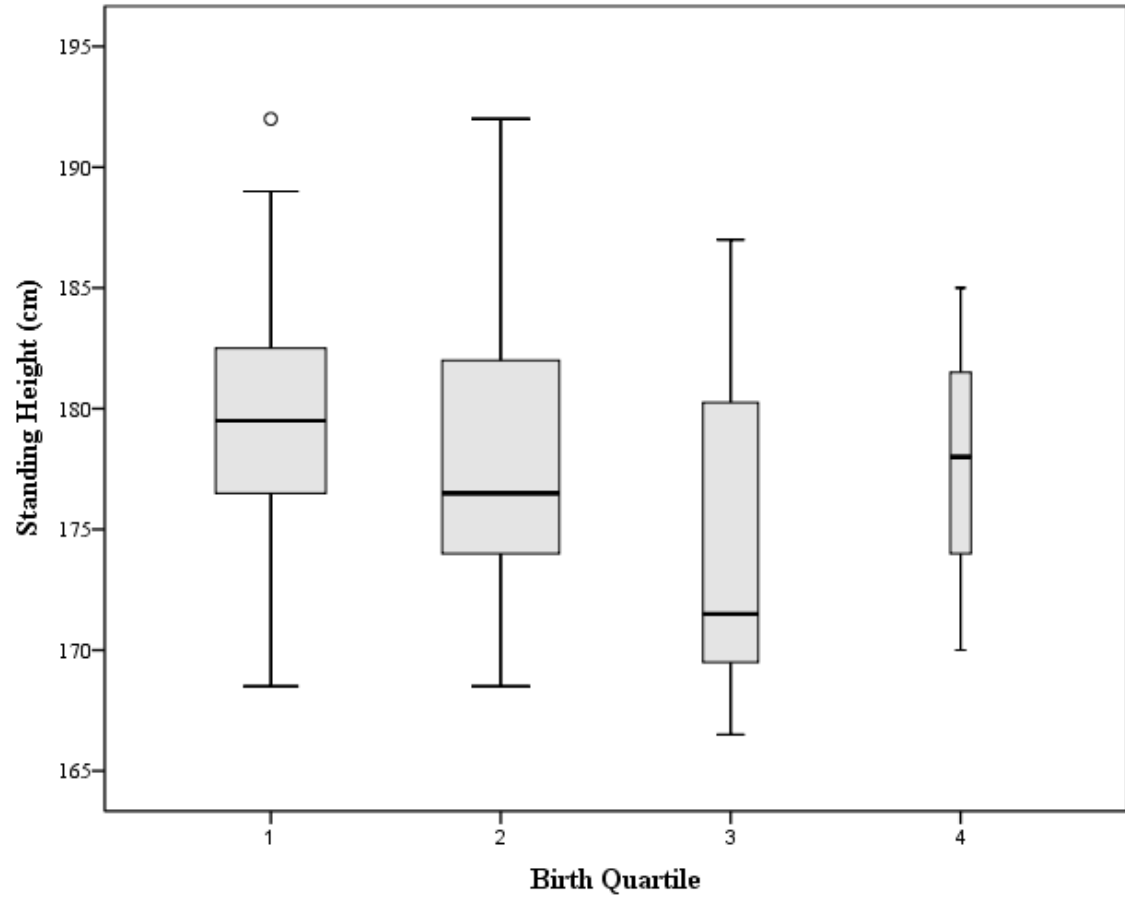


Figure 3. Standing height by birth quartile

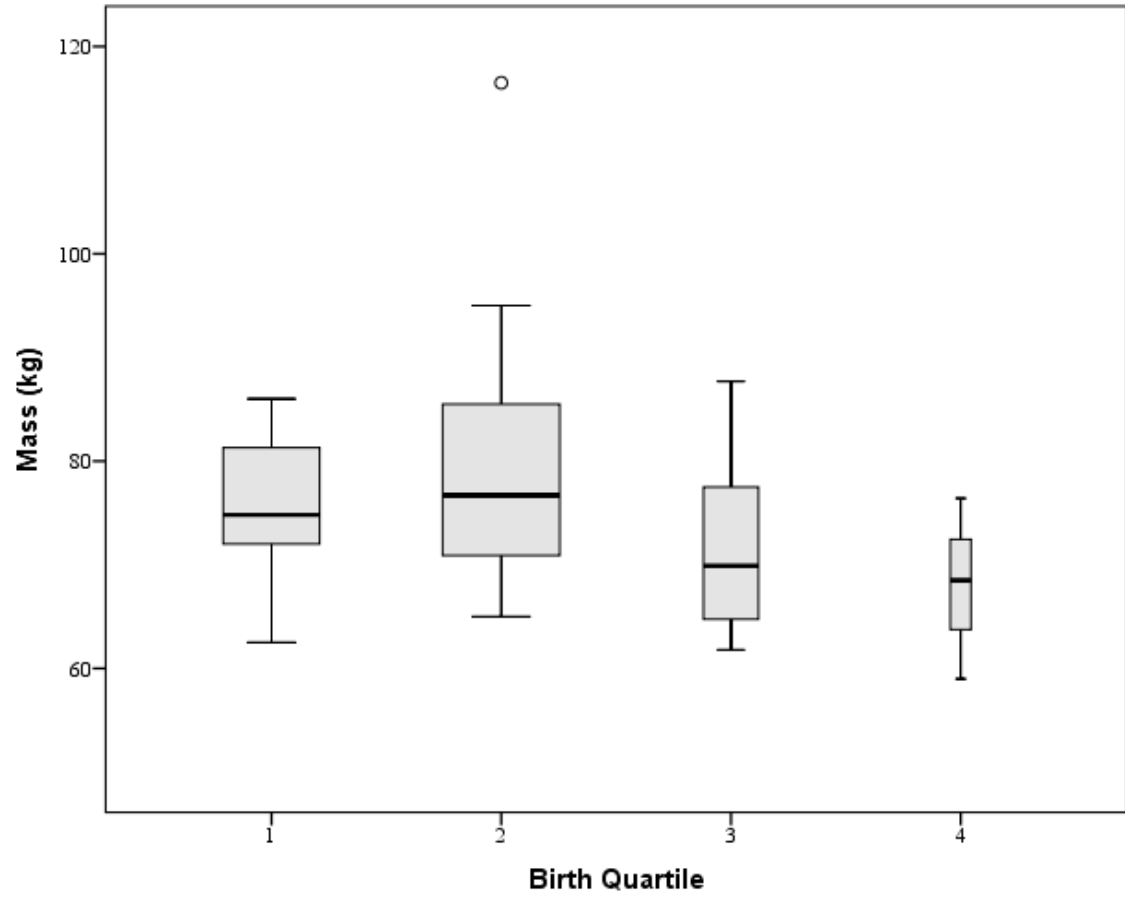


Figure 4. Body mass by birth quartile

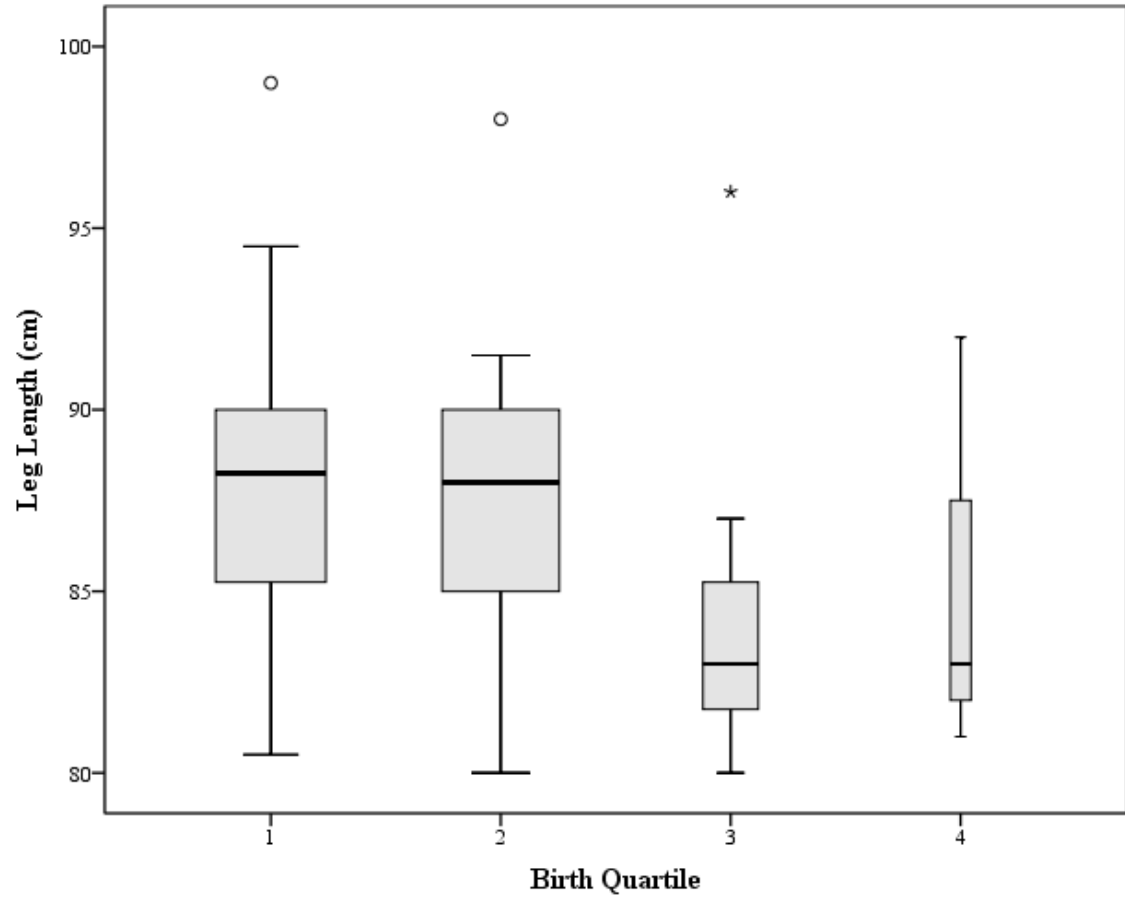


Figure 5. Leg length by birth quartile

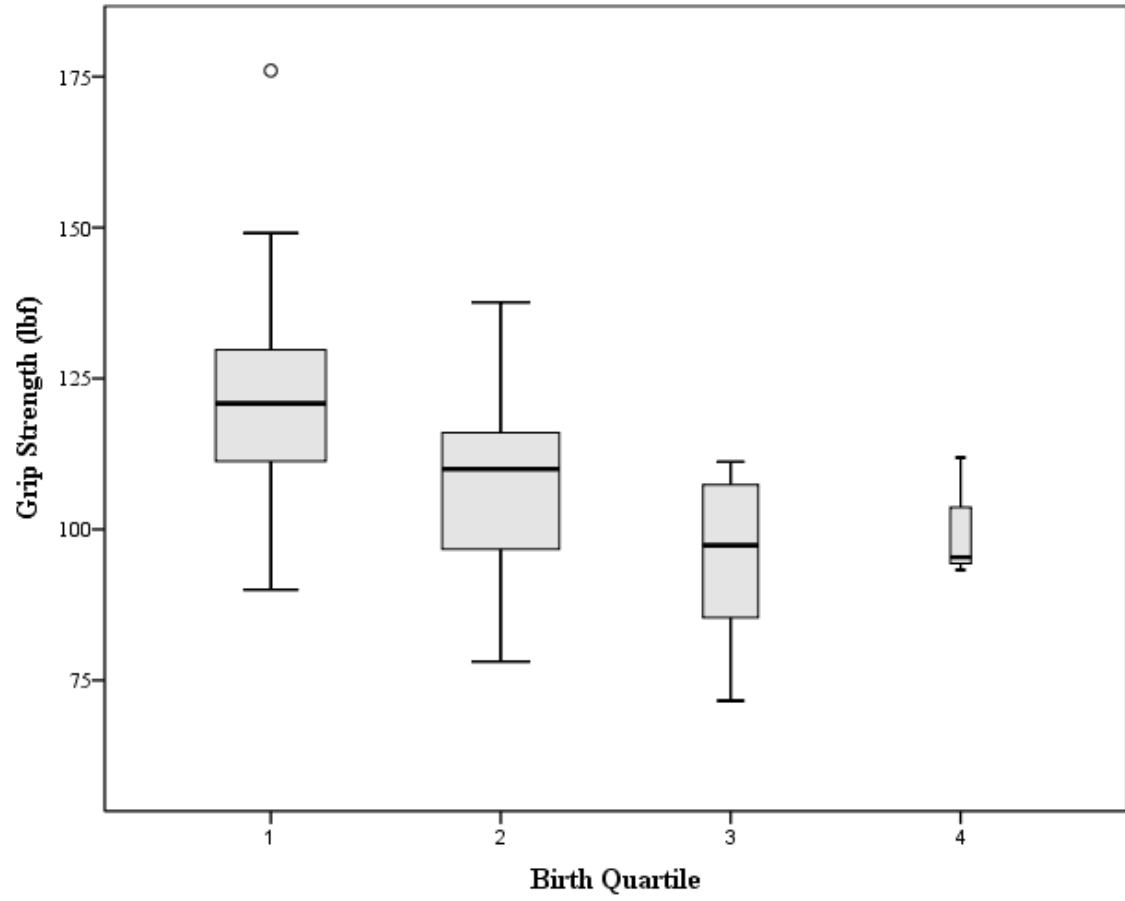


Figure 6: Grip strength by birth quartile

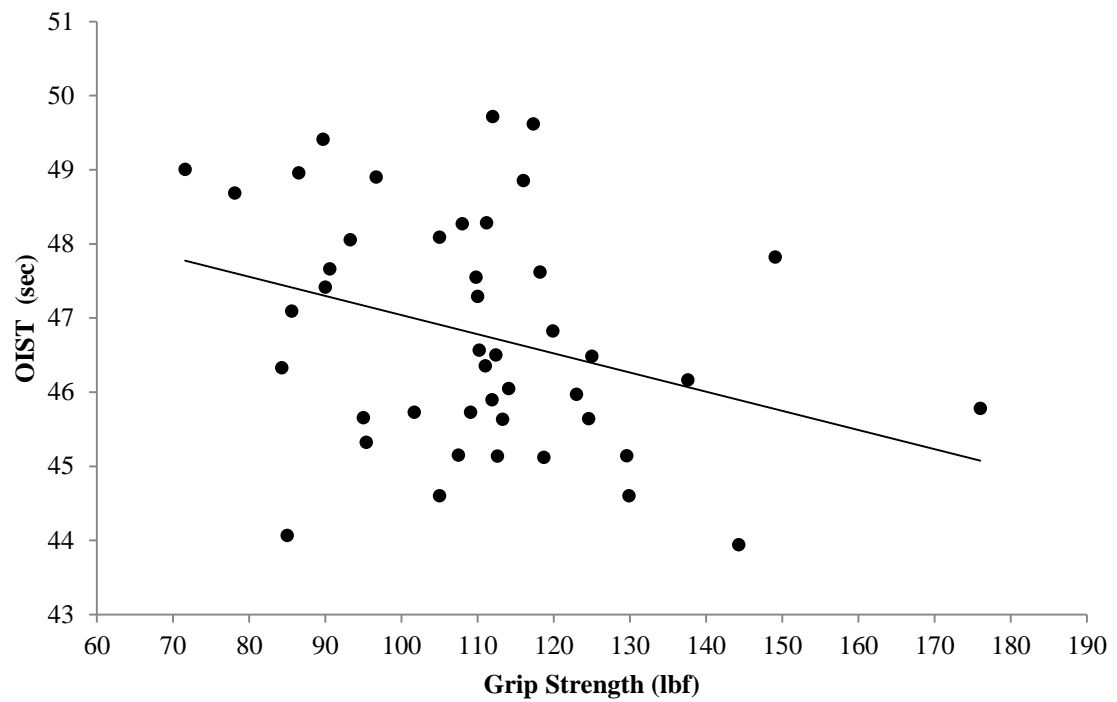


Figure 7. OIST vs Grip Strength

Note: skating ability is inversely related to test time; thus, the lower the test time, the higher the skating ability of the participant.

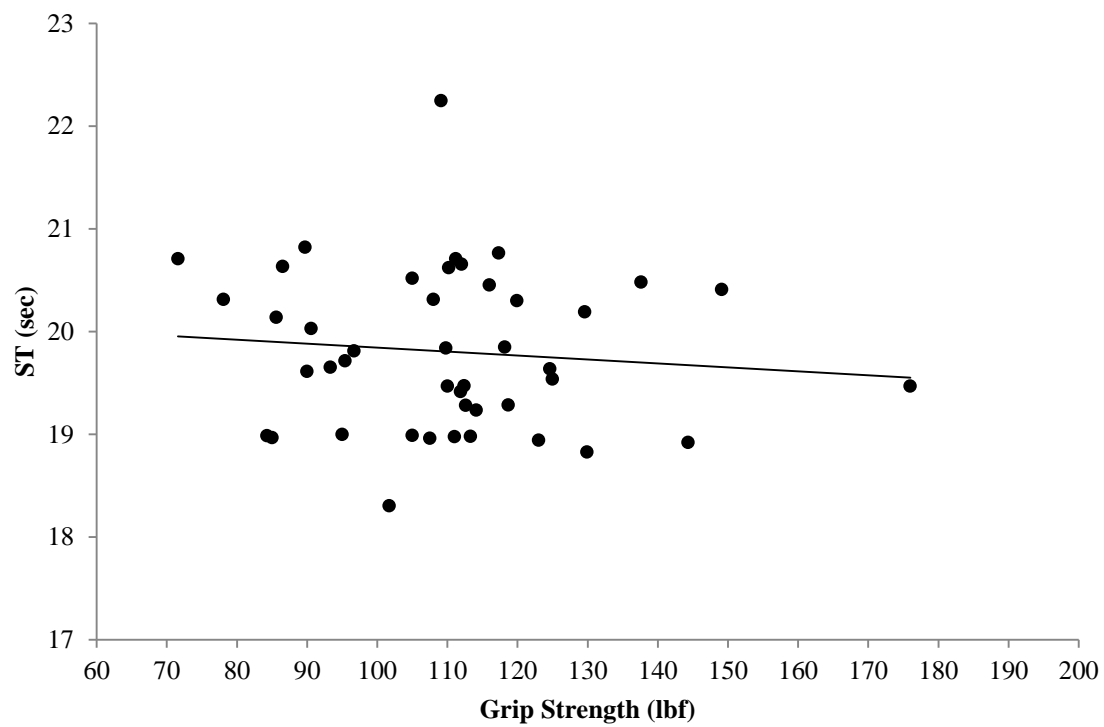


Figure 8. Sabre Test vs Grip Strength

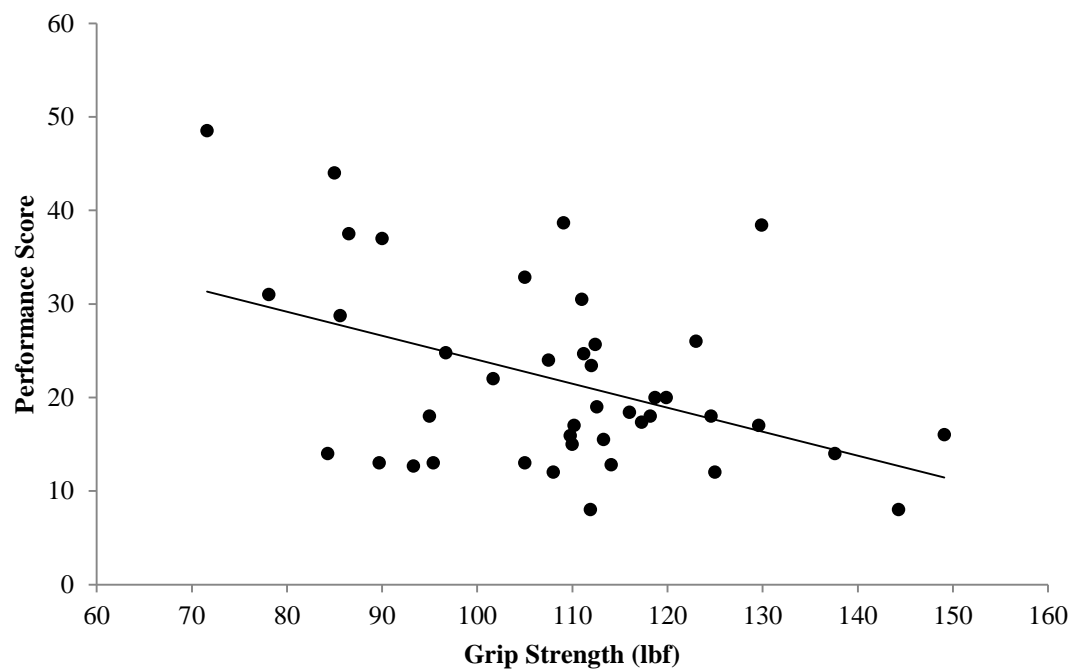


Figure 9. Performance Score vs Grip Strength

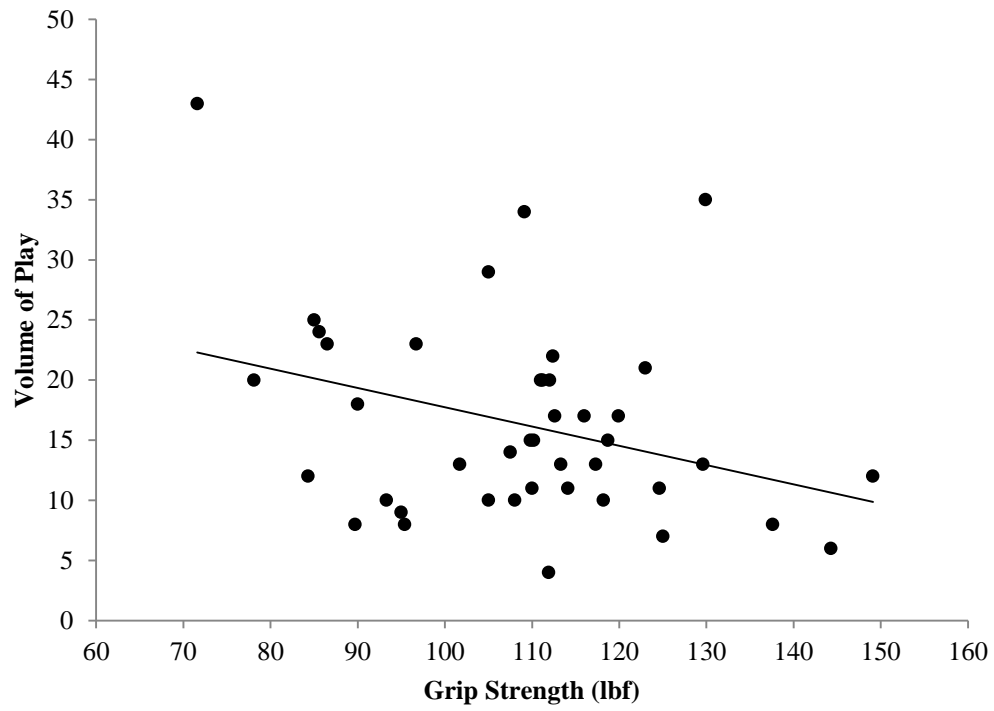


Figure 10. Volume of Play vs Grip Strength

Appendix A - Participant Consent Form

LETTER OF INFORMATION AND INFORMED CONSENT

Date: August-November, 2013

Project title: THE RELATIVE AGE EFFECT IN MINOR LEAGUE ICE HOCKEY:
AN INVESTIGATION OF THE 'UNDERDOG EFFECT'

Principal Investigator: Kelly L. Lockwood, Associate Professor

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Student Investigator: Matthew Belgiorgio, MSc Candidate

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You are being invited to participate in a study entitled "THE RELATIVE AGE EFFECT IN MINOR LEAGUE HOCKEY PLAYERS: AN INVESTIGATION OF THE 'UNDERDOG EFFECT'." The study will be conducted by Dr. Kelly Lockwood, who oversees the On Ice Performance Laboratory at Brock University.

BACKGROUND

The Relative Age Effect (RAE) is defined as a skewed birth date distribution within a specific age cohort of athletes. In the sport of ice hockey, it has been recognized that a higher proportion of players are born earlier in an age cohort. The purpose of this study is to further our knowledge of the Relative Age Effect by investigating the relationship between birth date and skating ability, and the relationship between birth date and in-game performance. It is proposed that relatively younger players may possess higher skating abilities and have higher in-game performance scores, to compensate for a lower level of physical maturity.

WHAT IS REQUIRED

1. You will be required to provide information such as your playing history, hockey-related traits such as handedness and playing position, and birth date.
2. You will undergo a battery of dryland assessments including height, weight, and a measure of grip strength. This will require approximately 30-60 minutes of your time, scheduled with your team.
3. You will undergo a battery of timed on-ice tests that will assess various aspects of your skating ability. This will require no more than 1.5 hours of your time, and will require you to dress in full hockey equipment.
4. Your coach will be contacted to obtain a videotape of a regularly scheduled game for further analysis.

RISKS AND BENEFITS OF PARTICIPATION

Although the battery of on-ice tests performed by the participants will require physical exertion, the intensity and nature of the activity is not considered to be any more strenuous than a typical on-ice non-contact hockey practice or game. The nature of the activity is also no more dangerous than that which you would experience in a typical game or practice. However, as in typical games and practices, there is a risk of injury. In order to minimize the consequences of such accidents, you will be required to wear your equipment. Researchers will also be present on the ice and ready to respond. In advance of the testing, you will be asked to come physically and mentally prepared. Please be well nourished, well hydrated and well rested. It is also your responsibility to have your skates sharpened. One of the benefits of your participation in the on-ice tests is that they provide an accurate assessment of each aspect of your skating ability, allowing you to identify your strengths and weaknesses. In short, this battery of on-ice tests could be a useful tool for self-assessment.

CONFIDENTIALITY

All data collected will remain confidential, and will not be made available to any other third parties. Data will be kept on in a locked, secured cabinet in our laboratory at Brock University, and/or on file on a computer that will be protected by password, and only accessible to the principal and student investigators. Data will be held for 5 years, after which time data will be shredded and deleted from computer files.

PUBLICATION OF RESULTS

This study may be adapted to be published in peer-reviewed scientific journals, magazines and/or presented at academic conferences. Feedback from this study, as well as how to obtain any published material, will be available to players, parents or coaches through Dr. Kelly Lockwood or Matthew Belgiorgio. Data provided in the form of feedback will be coded so that individual data will be confidential. This means that on ice skating test times and in game performance scores will not be represented by any information that can identify an individual player.

This study has been reviewed and has received ethics clearance through the Research Ethics Board at Brock University [file #12-259]. If you have any comments or concerns about your rights as a research participant, please contact the Research Ethics Office at (905) 688- 5550 Ext. 3035, reb@brocku.ca.

In order to participate in the described study, this document must be read and signed. Because participants are under 18 years of age, the participants consent must be accompanied by a parental/guardian as outlined below. Completed informed consent is mandatory for participation.

For Participants to complete:

• In signing this form, I _____ (*Participant's Name*),
acknowledge that I have received an explanation about the nature of the study and its
purpose. I give my permission _____ (*Participant's Name*) to participate in
the research described above conducted by Dr. Kelly Lockwood.

1. Participation is voluntary. Participants can withdraw from the program at any time. An open door policy with regard to athletes/parents asking questions about the study and participation will be maintained in confidence. Participation or non-participation has no impact on the player's standing with their coach or with their team.
2. Participant's names and data will be confidential. All participant names will be coded so that the data collected cannot be associated with the participant upon publication.
3. Participants will receive a copy of the Informed Consent Form and their own individual results upon completion of the project. Participants are asked to retain it for their personal records.

Participant's Name: _____ **Signature:** _____

Date: _____

Parent/Guardian Name: _____ **Signature** _____

Date _____

Appendix B – Player Questionnaire/Physical Measurements

1. Player Last Name: _____ First Name _____
2. Date of Birth (*Eg. January 01, 1997*): _____
3. Playing level: **AA** **AAA**
4. Team Name: _____
5. Playing Position: **Defense** **Forward**
6. Player shoots: **Left** **Right**
7. How old were you when you began playing organized ice hockey? : _____
8. Have you ever played A level hockey? If so, how many years? _____
9. Have you ever played AA level hockey? If so, how many years? _____
10. Have you ever played AAA level ice hockey? If so, how many years? _____
11. Standing height: _____ cm
12. Sitting height: _____ cm
13. Body Mass: _____ kg
14. Hand Grip Strength:

Trial	Hand	Peak Force (lbf)	Mean force (lbf)	Time to peak force (sec)	End Force (lbf)	% Decrement
1	Left					
	Right					
2	Left					
	Right					

Appendix C - Team Sport Assessment Procedure

Variables	Actions	Definitions
Conquered puck (CP)	<ol style="list-style-type: none"> 1. Intercept pass 2. Puck Conquered form opponent 	A puck is conquered when a player takes possession of the puck from an opponent, and controls it for a while. The player has also conquered a puck when the performs an action to redirect the puck voluntarily to a teammate, even though he did not retain it for a while
Received Pass (RP)	<ol style="list-style-type: none"> 1. Pass from a teammate 	A received pass from a teammate is awarded when the player has control over the puck or when he performs an action to redirect the puck voluntarily to a teammate even though he did not retain it for a while
Received puck	<ol style="list-style-type: none"> 1. Puck received after an icing call 2. Free puck 	This occurs when a player takes control of the puck following an opponent's icing, a missed pass of an opponent or a teammate in a neutral context, i.e. when the puck is free. The player takes control of the puck without having to perform an action or a particular move.
Neutral Pass (NP)	<ol style="list-style-type: none"> 1. Pass performed by a player to a teammate 2. Routine pass 	A routine pass that did not create a threat for the opponent or did not precede a shot on goal. All passes in which the main purpose is to keep control of the puck and to progress towards the opponent's goal, without performing a direct action towards the opponents goal.
Offensive Pass (OP)	<ol style="list-style-type: none"> 1. Pass Preceding a shot on goal 2. Pass in which an opponent must 	Pass to a teammate that puts pressure on the other team and, most often, leads to a shot on goal. Also included

	protect oneself	in this category are passes made to a teammate and immediately redirected towards the opponent's goal.
Lost Puck (LP)	<ol style="list-style-type: none"> 1. Bad pass 2. Unsuccessful icing 3. Direct loss of puck control 	The player, after having control of the puck, loses it to an opponent, either due to a technical-tactical error or because of a bad pass. The puck must be taken back by an opponent. A lost puck picked up by a teammate is considered to be a neutral pass by the player who lost control of it
Successful shot (SS)	<ol style="list-style-type: none"> 1. Shot on goal 2. Redirected shot 	A goal or a shot stopped by the goaltender or an opponent if the goaltender is out of his normal position. The shot must be directed on goal and have the potential to result in a goal, i.e. the shot would go in if the goaltender was absent or out of position. A shot that hits the goalposts or the crossbar and does not result in a goal is considered a direct loss if the puck is picked up by an opponent or a neutral pass if the puck is picked up by a teammate.
Successful Icing (SI)	<ol style="list-style-type: none"> 1. Defensive icing 	After controlling the puck in the defensive zone, the player clears his defensive zone by sending the puck into the offensive zone. A successful icing occurs when the player in control of the puck clears his defensive zone (up to the blue line) when the opponents are attacking.
Hindering Progression (HP)	<ol style="list-style-type: none"> 1. Body check 2. Check with hockey stick 3. Covering or 	Action hindering the progression of an opponent carrying the puck. The player, with a body check, a

	shadowing an opponent 4. Back Check	block or by a tight shadowing, provokes a loss of puck possession from the opponent, by pushing him toward the board, preventing him from making a pass or an icing. The puck must be lost by the opponent and taken back by another player (opponent or team-mate) without the voluntary action of the opponent (who first had control of the puck).
Blocked Shot (BS)	1. Blocked shot 2. Slide in front of the puck	A shot on goal by an opponent is blocked or diverted away from the goal by a player. Action or a player to block an opponent's shot or have the shot diverted away from the goal.
$\text{Volume of play (VP)} = \text{CP} + \text{RP} + \text{RR}$ $\text{Efficiency index (EI)} = (\text{CP} + \text{OP} + \text{RP} + \text{SS}) / \text{LP}$ $\text{Performance Score (PS)} = \text{EI} + \text{VP}$		

Appendix D – Pilot Study

A preliminary study was conducted to explore the RAE in the OMHA AAA Minor Midget (aged 15-16) ice hockey players. The objective of this study was to determine if a significant Relative Age Effect was present in the Minor Midget South-Central Triple 'A' (SCTA) Division of the OMHA. The secondary objective of this study was to investigate the maturation-selection theory that explains that the RAE occurs due to a tendency for coaches to select specifically based on physical maturity.

Methods

Participants

Data was collected from a total of 170 ($N = 170$) 15-16 year old AAA OMHA Ice hockey players, participating in a weekend-long 'showcase,' during which time each team played 2 games. All data were obtained from players who were participating in their teams' competitive games, and were injury-free. Each player reported for testing either before or after their scheduled game took place. Prior to testing, each player and a parent or guardian signed a consent form and were informed of the purpose and procedure of the testing involved.

Experimental Design

This study utilized an observational cross-sectional study design, whereby possible association between several variables were investigated in a sample population of elite ice hockey players. In all players, relative age as well as standing height and body mass were determined, and a subset of the original sample ($n = 105$) also had grip strength and leg length determined. All physical assessments were designed to assess

physical maturity levels in players, so that it could be determined if they were associated with their relative age.

Determination of Relative Age

Relative age is defined as the age of a player within their specifically defined age cohort in which they are competing. For example, because the OMHA defines the age cohorts as beginning January 1st and ending on December 1st of a given year, the players with birthdates in January are considered to be the ‘relatively oldest’ players, while the children born in December would be considered ‘relatively youngest.’ The relative age of each player was obtained by recording their exact birth date on the player questionnaire that each participant received.

Anthropometric Measures

All anthropometric measurements were conducted at the ice rink either before or after the players participated in their regularly scheduled game. Participants were asked to wear loose fitting clothing and be barefooted. With the help of an investigator, the mass (kg), standing height (cm) and sitting height (cm) of each participant was determined using a portable scale and stadiometre. In order to determine leg length, the seated height of the participant was subtracted from their standing height (Sherar et al., 2007).

Determination of Hand-grip Strength

The hand grip strength (kg) of each participant was determined at the ice rink, immediately following the anthropometric measures. Measurements were determined using a digital dynamometer connected to a computer system. Participants stood during the test, with their hands at their sides, in front of a computer monitor on which

instructions are provided. The dynamometer was held in one hand in a standard position (as per the *American Society of Handgrip Therapists*) with shoulders adducted, and the forearm in a neutral position and the wrist in a neutral position just necessary to hold the device (Hager-Ross & Rosblad, 2002). Towels were available if the participants needed to dry the hand, in order to ensure that the hand did not slip during the test.

The apparatus was programmed to measure grip strength over a period of 5 seconds, during which time peak force (kg) was recorded. Once the initial measurement was taken, the participants repeated the procedure with the other hand. Hand grip strength was represented as the maximal force measured by a single grip (Hager-Ross & Rosblad, 2002).

Statistical Analysis

Relative age, standing height, leg length, body mass, and grip strength were entered into SPSS (SPSS Inc, Chicago, IL), and descriptive statistics were determined. To test the first hypothesis that an RAE exists in the sample, birth dates were re-coded to represent the quartile in which their birth dates were found. For example, birth dates in the months of January, February and March will be designated Quartile 1 (Q1), whereas players born in the months of October, November or December will be designated Quartile 4 (Q4). To determine if an RAE was present, a Chi-Squared Goodness of Fit Test was used to compare the observed birth date distribution with the theoretically expected distribution (25% of the births in each quartile). An alpha level of $p \geq 0.05$ was set for significance testing.

In order to test the second hypothesis, the relative age variable was coded as the number of days between the players' birth date and December 31st of that same year,

creating a range from 0-365) (Fenzel, 1992). Spearman Rank-order Correlation coefficients were used to measure the association between relative age and physical maturity variables. An Analysis of Variance (ANOVA) was used to compare means across quartiles, using Tukey's *post hoc* test to compare across individual quartiles. Again, an alpha level of $p \geq 0.05$ will be set for significance testing.

Results

Descriptive statistics for the participants are shown in table 1. Descriptive statistics for forwards and defensemen are also shown separately as it is commonly believed that defensemen are generally selected to be larger than forwards.

Table 1. *Descriptive Statistics for participants.*

	<i>n</i>	ABM	Height (cm)	Leg Length (cm)	Body Mass (kg)	Hand-Grip Strength (1bf)
Forwards	109	4.9	175.1±6.8	84.4±5.2	71.5±10.1	115.3±18.4
Defense	61	4.8	177.2±4.8	86.1±4.0	72.1±7.6	111.3±15.6
Total	170	4.9	175.8±6.2	85±4.8	71.7±9.3	113.9±17.5

Note: ABM = Average Birth Month (1= January, 2=February, etc).

Birth frequencies by quartile of all participants are presented in Figure 1. As expected, chi-squared analysis revealed that the birth date distribution was significantly skewed towards the beginning of the year ($X^2 = 36.541, p < 0.001$). Chi squared analysis of the birth date distributions for forwards and defense was also conducted separately,

showing significant RAEs in both groups ($X^2 = 26.890, p < 0.001$, and $X^2 = 10.410, p = 0.015$, respectively).

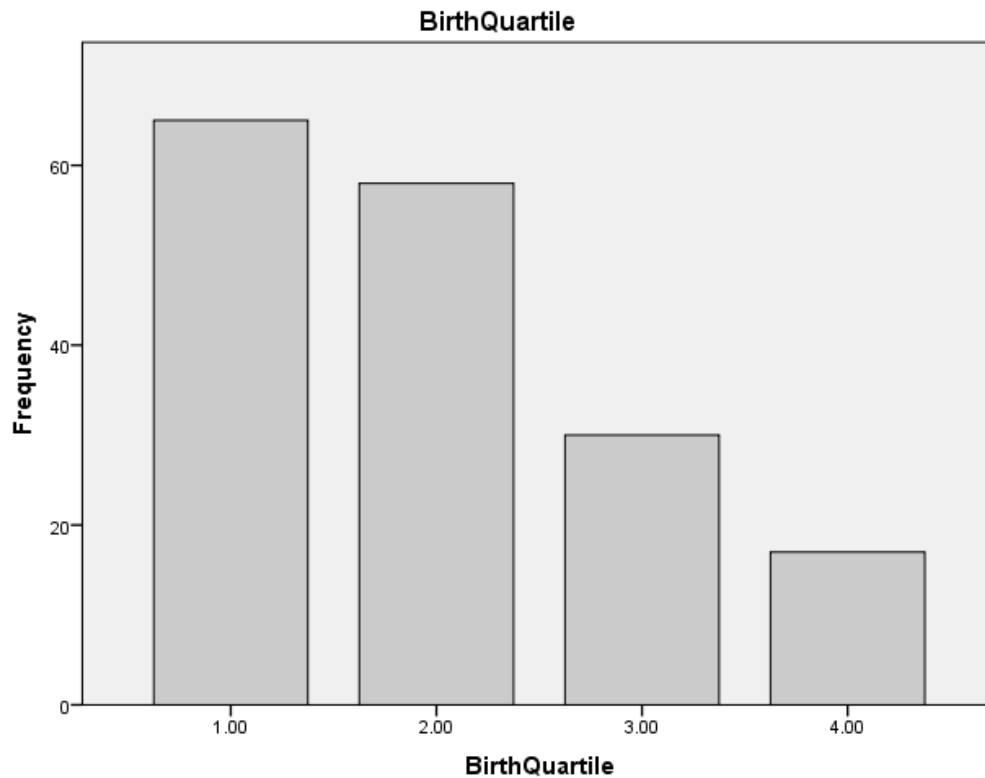


Figure 1: Distribution of players by birth quartile.

Descriptive statistics across quartiles are presented in Table 2. An ANOVA failed to reveal significant differences across the 4 quartiles for height ($F = 0.244, p = 0.87$), Body mass ($F = 0.428, p = 0.73$), and leg length ($F = 0.87, p = 0.461$). However, a significant difference across quartiles for grip strength measurements was found ($F = 2.71, p = 0.49$). Tukey's *post hoc* analysis revealed that although no significant differences across quartile pairs can be seen, a trend can be seen showing the mean values of grip strength descending from quartile 1 to quartile 4 (Table 1). Also worth noting is

that the difference in mean grip strengths between Quartile 1 and Quartile 4 was approaching significance ($p = 0.058$).

Table 2. *Analysis of Variance for descriptive statistics across all quartiles.*

Variable (n)	Q1	Q2	Q3	Q4	p
Height (170)	175.97±6.4	175.54±5.5	176.5±6.9	175.12±6.5	0.865
Leg Length (105)	85.91±4.48	84.39±4.15	84.98±6.65	83.64±4.35	0.461
Body Mass (170)	72.44±10.7	71.9±8.7	70.19±8.5	71.18±6.7	0.734
Grip Strength (105)	117.37±19.4	115.4±16.6	109.58±12.6	100.46±17.11	0.049*

*indicates significance ($p < 0.05$).

Spearman ranked correlation coefficients were used to investigate the association between relative age and the descriptive variables measured. Positive yet non-significant correlations were found for between relative age and the descriptive variables Height ($r = 0.013$, $p = 0.866$), leg length, ($r = 0.080$, $p = 0.419$) and body mass ($r = 0.040$, $p = 0.601$). A positive correlation was, however, shown to be statistically significant between relative and grip strength ($r = 0.203$, $p = 0.038$).

Discussion

The primary purpose of the preliminary study was to investigate if an RAE existed in a sample population of elite 15-16 aged ice hockey players in the Ontario Minor Hockey Association (OMHA). In this sample population investigated, chi-squared analysis revealed a significant RAE. A significant RAE was also observed when looking at the group of forwards and the group of defensemen, separately, indicating that the skewed birth date distribution is not specific to the defense, a position traditionally known to contain larger players. When looking at the descriptive statistics across playing positions, none of the descriptive variables (height, leg length, body mass, grip strength) varied significantly.

The second purpose of this study was to investigate how the descriptive variables are associated with the relative age of the players. It was found in our sample that anthropometric measures were consistent across all quartiles, and did not significantly correlate with relative age. These findings are consistent with past literature (Sherar et al, 2007, Baker et al, 2008), suggesting that although players that progress to elite levels of play are also relatively large in stature and body mass, this is only due to the fact that they are physically mature. An important limitation of this study, however, was that some height and bodymass measurements were obtained via the RinkNet website, which may have contained outdated or different methods for the measurement of the players.

In addition to anthropometric measures, grip strength was also assessed, and was found to be positively associated with relative age (relatively older players were ranked higher in grip strength compared to relatively younger players). An ANOVA also found statistically significant differences for grip strength means across quartiles. Although no significant pair wise comparisons were found, a trend was found indicating that grip

strength was highest in the quartiles containing relatively older players. This may have been a result of a lower sample size of players from whom grip strength values were collected ($n = 105$), reducing the statistical power. Nevertheless, the tendency for relatively older players to have a stronger grip strength measurement, as seen in this study, provides evidence that although players are preferentially selected for elite levels of play according to physical maturity, there still exists a physical inequality among the players, independent of their anthropometric measures. However, it could be that grip strength has little or no influence on selection, since players of varying relative age within one playing level had significantly different grip strengths.

In conclusion, the preliminary results indicated a strong RAE in our sample population, and provided evidence that physical strength varies within a sample of competitive Minor Midget hockey players. Specifically, players born earlier in the year appeared to have larger grip strengths compared to players born later in the year. The next step in this investigation will be to investigate the relationship between relative age/physical maturity, and technical skills among a subset of this sample.